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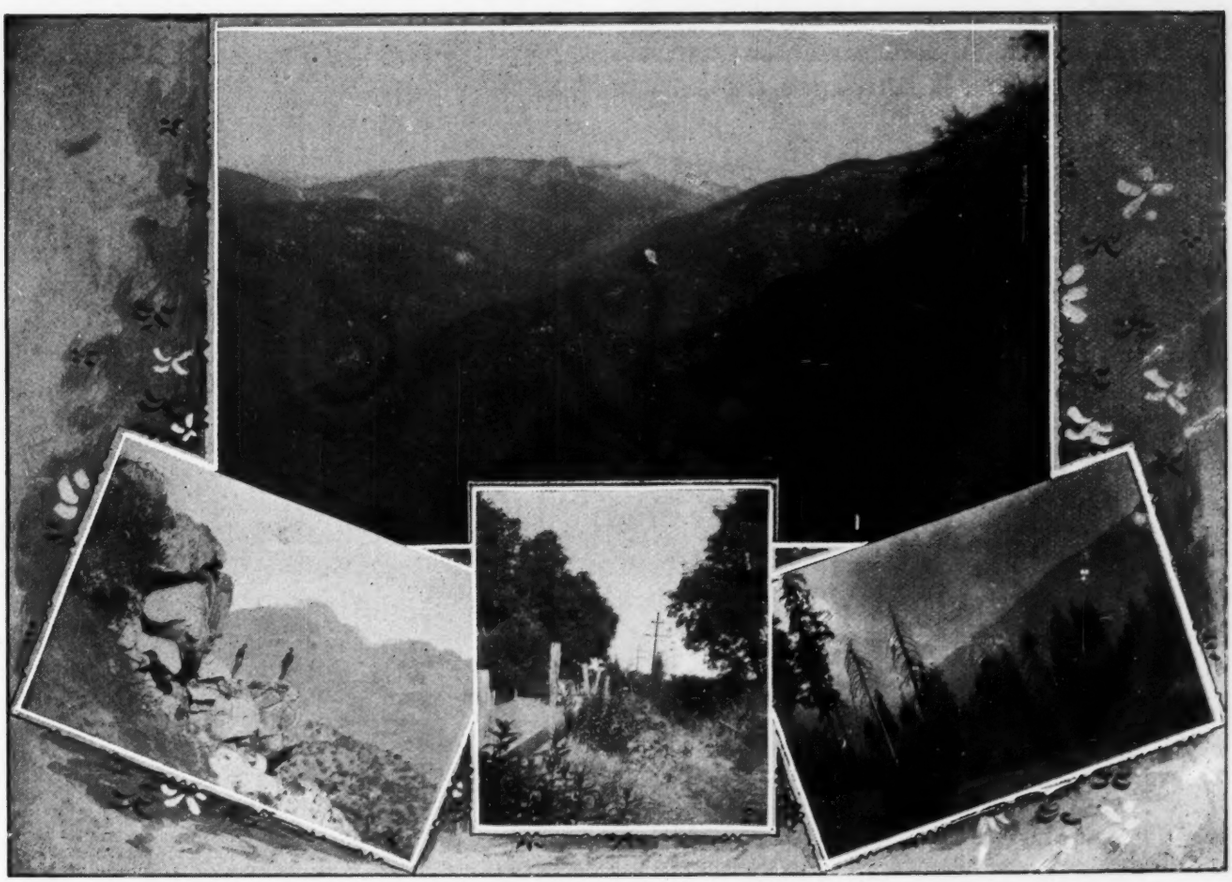
THE JOURNAL OF ELECTRICITY, POWER AND GAS.

VOLUME IX. SAN FRANCISCO, JANUARY, 1900. NUMBER 1.

The Mount Whitney Power Transmission.

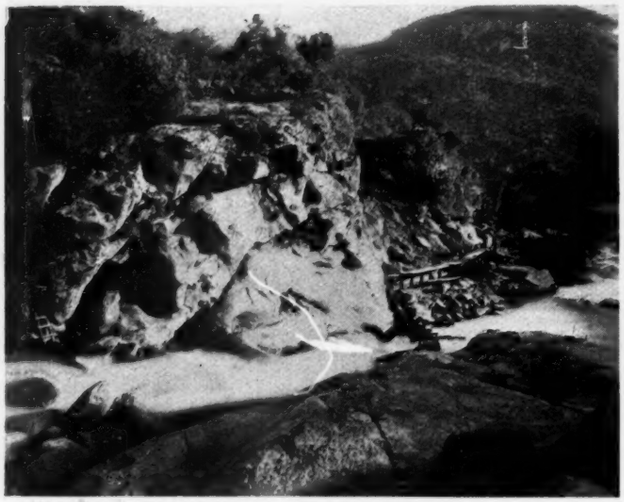
BY ROBERT McF. DOBLE.



NUMBERS 1, 3 AND 4 ARE CHARACTERISTIC VIEWS ALONG THE FLUME. NUMBER 2 IS A POLE-LINE SCENE.

THE great and fertile San Joaquin Valley has gradually advanced from cattle raising, which marked the pioneer state, through wheat farming to the successful production of grapes, peaches, prunes, oranges and lemons in addition. This material and permanent advance has been brought about by irrigation, and so evident are the benefits to be derived therefrom, that vast sums of money have been expended in the construction of canals and ditches to conduct the waters of the rivers out upon the fertile valley lands, and so valuable is the water that vast additional sums have been expended in litigation over water rights. Water must be had at any reasonable cost and those so situated as to be unable to procure a supply from the ditches resort to pumping from wells. This has proven successful, but the fuel cost is great, and in order that the complete development of the fertile lands of Tulare county might ensue, it became necessary that some cheaper power than either steam or crude oil engines should be made available. At the season of the year when the water is needed for the orchards the supply in the rivers is totally inadequate, but experience has proven that there is an abundant subterranean supply within easy distance from the surface, and the solution of the problem is found in the installation of electrically-driven pumping plants.

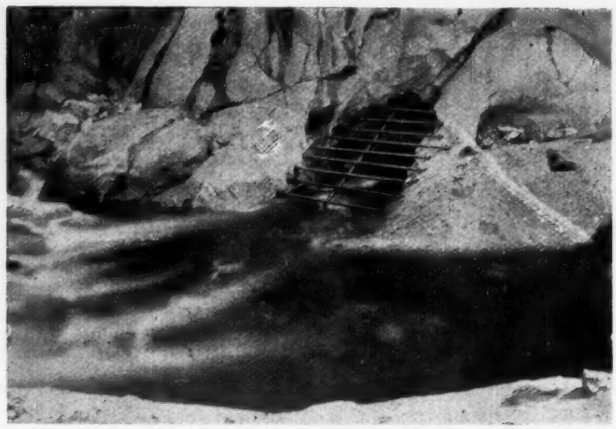
The foregoing condition of affairs has called into exist-



TUNNEL INLET, FALLS AND TEMPORARY SUSPENSION FLUME.

ence the electric power transmission plant which is the subject of this article, and being the latest, and having the advantage of experience and improvements gained from other similar plants, it is the most modern and best equipped installation to date. For more than eight years the scheme of bringing electric power from the Kaweah River to Visalia and the other towns of Tulare county, was agitated, but it was not until in June, 1899, that it was realized, and its completion marks an important event in the history of the county of Tulare, making possible a material advancement in all industries.

Though a river of considerable importance, the Kaweah is little known outside of the vicinity where it enters the San Joaquin Valley, soon after which it disappears to contribute to the subterranean supply of water that is always



TUNNEL INLET, AFTER THE GRIZZLY HAD BEEN PLACED.

available. It rises in the high Sierras which lie northeast of Visalia, distant about sixty miles. The east fork, on which the power house is located, has its source in the near vicinity of Mineral King and that part of the Sierra Nevada range known as Hockett's Meadows, the elevation

THE "PUZZLE PICTURE" FACE IN THE FOREGROUND IS A NATURAL PHOTOGRAPHIC FREAK.

DIVERSION FALLS, WITH MOUTH OF TUNNEL THROUGH DIVERSION ROCK.

of which is 13,000 feet above the level of the sea. The average altitude of the country drained by this stream is about 7000 feet; therefore the snow remains very late in the summer, while many of the higher canyons have perpetual snow, thus forming a great natural reservoir.

A famous and strikingly prominent feature at Mineral King is a pointed mountain peak, well named "Sawtooth," distinctly visible from the valley in clear weather, where it appears in the eastern sky as a pure white point piercing the heavens. In the fall of the year Sawtooth is brown and bare. From its summit, 13,200 feet above the sea, on a clear day may be seen dozens of mountain giants, one among the number rearing its head 14,552 feet towards the heavens. This is Mount Whitney, the monarch of the Sierra Nevadas and the acknowledged king of all mountains in the United States. As becomes his majesty, his throne is placed toward the east and all of his subjects are toward the north and west. From the top of Sawtooth one can pay homage to this mighty monarch and at

SOME OF THE ROUGH COUNTRY ALONG THE FLUME.

the same time hold communion with Mount Tyndall, Mount Brewer, Mount Kaweah, Mount Williamson and scores of other members of the royal mountain family.

Below and around its base are the jewels of a prince. Seventeen lakes sparkle and glisten as the sun falls gently upon their virgin bosoms, and their brilliancy would pale into insignificance a million Kohinoors. The lights and shadows of the grand peaks and bottomless canyons fill the beholder with reverence and awe, and as he stands subdued in the presence of the mightiest handiwork of the Creator, the gentle wind sings a melody most harmonious and the soul is filled with peace and tranquility.

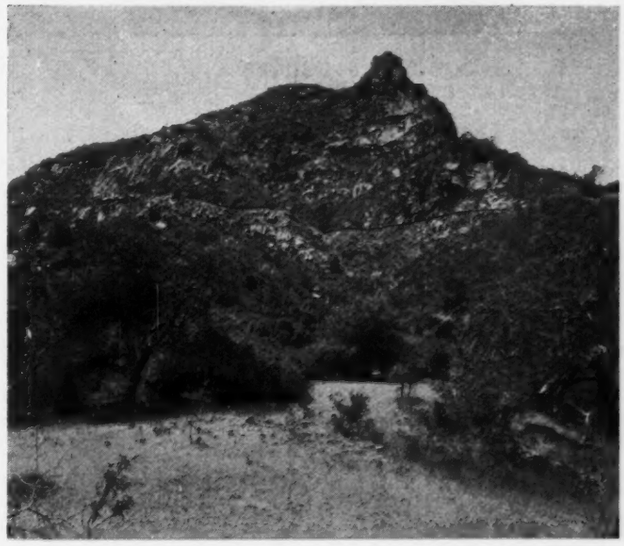
But in December the scene changes! The winds are no longer gentle and clouds are fast filling the canyons. Flashes of lightning, followed by the roar of thunder, admonish all living things to seek shelter. The wind increases in violence, the flashes of lightning are almost continuous, the peals of thunder shake the very mountains! In this great electrical display Nature needs no dynamos, no transformers, no wires. Down in the valleys

LUMBER CHUTE, FLUME AND TRESTLE, ABOUT 500 FEET BELOW THE TUNNEL.

and along the foothills the rain is falling to make glad the hearts of the husbandmen, but where royalty is enthroned it never rains. Sawtooth needs to be refreshed but only with eternal snow.

In June the scene again changes! The warm sun covers the mountains with a flood of warmth and beauty, the snow is resolved into tears because the unerring law of nature has decreed that it can no longer linger on the summit of proud Sawtooth. Slowly the silver-threaded rivulets wind down the mountain side. In Monarch Lake a short stop is made, and the melted snow, now changed to gems, makes its last obeisance to Sawtooth. Then down deep gorges and over huge boulders the beautiful brook joyously sings its way to meet the streams from Farewell Gap, Eagle Lake, Lady Franklin Lake and Timber Gap, mingling with them and forming the sparkling Kaweah.

This stream, fed by living waters from the snow-clad, cloud-capped mountains, winds its way through the Mineral King valley, then down the canyon over precipices



FLUME AT SUMMIT CLIFFS, ONE MILE FROM THE PENSTOCK.

and through gorges. For countless ages it has continued its course undisturbed, being joined by the Marble Fork, the South Fork and the North Fork, as well as countless smaller tributaries, together forming a noble river, bearing the waters from a drainage area of 619 square miles. The foothills are reached and then the plains, where the river begins to sink into the ground as well as branch out in many small streams, and it soon has nearly all disappeared, although at one time a portion of the waters finally reached Tulare Lake. But the handiwork of man has wrought a change. The singing waters are to be pressed into service for furnishing means to quench the parched plains, that there may be green fields that shall forever be green and boundless acres of luxuriant orchards and orange groves.

SNOW-RANGES IN THE BACKGROUND WERE LOST IN THE PHOTOGRAPH.

"JIBBERALTER" OF THE MOUNT WHITNEY FLUME, 300 FEET FROM THE PENSTOCK.

At a point distant about 45 miles easterly from Visalia, named Oak Flat, at an elevation of about 2400 feet above the sea level, a solid granite ledge crosses the river and forms a perpendicular bluff on the south side as well as a natural dam of about twelve feet in height above a pool below into which the waters of the river have been wont to rush with terrific force, tumbling over this natural dam in hasty confusion, forming a charming waterfall. For ages they have run their seemingly mad race over this granite and have worn it very smooth.

This unusual and remarkable natural dam is made more valuable by reason of a small pool just above it from which the water is taken through a tunnel, the exit of which is well above the river and beyond all danger from high water at times of freshets, thus guaranteeing the permanency and safety of the headworks, which is a vital necessity.

The tunnel was blasted through 47 feet of the toughest and hardest variety of solid granite, and its general dimensions are three feet wide and six feet high. Located on the south side of the river, its entrance is from the pool above the falls and is at right angles to the river channel, so that drift will be carried past at high water. It is further protected by a substantial grating so that there is no possibility of the tunnel becoming choked with debris.

A short distance from the entrance the tunnel curves so as to bring the outlet in a line about parallel with the river below the falls. About fourteen feet from the outlet a substantial framework of heavy redwood timber is securely fitted into place and made perfectly tight by concreting, and here the flume commences.

The bottom of the tunnel is located below the crest of the dam so that at the period of low water all will be diverted into the flume. Thus at high water there will be a surplus, so waste-gates and overflow-tables as well as stop-gates are placed in the flume close to the tunnel, as well as regulating-gates and sand-boxes.

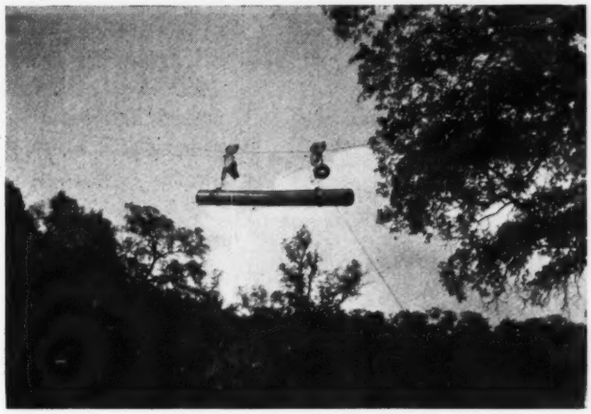
THE FLUME.

This flume is a very interesting piece of engineering and construction, being built as it is over a rough mountainous country. For thirty thousand feet it meanders

FLUME, PIPE LINE AND POWER HOUSE IN PERSPECTIVE.

along the steep mountain side, some places over granite boulders and smooth bluffs where even a goat would find it difficult to get a foothold. The river is gradually left below as the grade of the flume is much less than that of the river, and the flume approaches the ridge which gives it the appearance of running up hill, but in this case appearances are deceptive, as is proven by the rapid rate at which the water hustles through the flume to plunge headlong into the pipe.

It has a uniform grade of one foot in 200, or 26.4 feet per mile, giving a maximum velocity of flow of seven feet per second. It is three feet wide and two feet deep. The box is constructed of redwood boards 1½ inches



A 20-FOOT LENGTH OF WELDED PIPE "FLYING" UP HILL.

thick and 12 inches wide, there being three boards on the bottom and two on the sides. The joints are covered with battens one inch thick and four inches wide nailed on the inside. The box rests on sills of 4x4 spaced four feet apart, and is enclosed by posts and caps of 2x4 set at each sill. The posts support the sides and stiffen the structure, also form a support for the caps which are laid crosswise and on which the walk-board is laid. This walk-board is twelve inches wide and there are many places along the flume where it requires considerable nerve to walk over it, with the swiftly running water under you and a precipice of hundreds of feet over the side of the flume.

In many places trestles are required to cross ravines and other rocky places, and a number of trusses had to be used. The trestles were made of 4x4 redwood, all thoroughly braced, and throughout the work was done in a substantial manner. Steel cut nails were used: 8d for the battens, 12d for the boards and 20d for the caps and trestles, etc. At intervals sand-boxes and waste-gates have been provided, so that any sand which might find

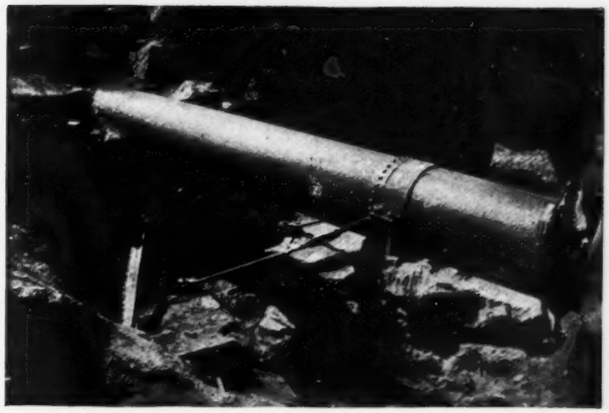
LAYING WELDED PIPE.

its way into the flume during the period of very high water when the snows are melting can be easily disposed of before reaching the pipe.

The form of construction adopted is very simple and efficient, loss by leakage amounting to almost nothing at all.

The maximum carrying capacity of the flume is 37 cubic feet per second and is greatly in excess of present needs, thus providing for the operation of additional machinery when the output of the present installation is disposed of.

The flume terminates in a sand-box and overflow-gate,



ANCHORAGE FOR PIPE LINE, WITH EYE-BOLTS, TURN-BUCKLES AND BANDS.

at right angles to which an apron leads off to the penstock. This apron is nine feet wide and its entrance is equipped with gates which regulate the amount of water which may flow into the pipe, and also with iron racks and heavy wire screens which serve to prevent the entrance of anything which might be floating in the water. The apron delivers the water into the penstock, which is 6x8 feet and 16 feet deep. It is securely strengthened by iron bolts passing through it and being made of a double thickness of redwood boards each 1½ inches thick; it is very substantial. Both the apron and the penstock are securely boarded over.

A telephone line extends the entire length of the flume and to the power house, so that the flume tender has instant communication for the purpose of properly regulating the water or for securing help should any be required. Storehouses are built at convenient points about a mile apart, each containing a telephone and sundry tools and materials for use in case of a break in the flume.

The flume tender's house is located at the end of the flume at the penstock, from which point one looks out over a panoramic scene of great beauty and grandeur. The power house and river seem almost straight down, being 1300 feet below, rugged mountains forming a becoming background. The views numbered 1, 3 and 4 in the illustration at the beginning of this article present characteristic scenes from different points along the flume. The smallest cut therein (No. 2) is a view on the pole line.

LOOKING DOWN THE PIPE LINE TO THE POWER HOUSE FROM THE PENSTOCK.

After the final survey and location of the headworks and the flume line, the next most important matter was from whence to get the lumber necessary to build the flume and how to get it onto the rough and forbidding mountain sides where it would be required. This finally was solved by leasing the Atwell sawmill, located on the east branch of the Kaweah river about 14 miles above the head of the flume and about 4000 feet higher in elevation. The mill went merrily to work, converting magnificent redwood giants, the *Sequoia Gigantea*, into flume boards and timbers. The tall tree that today proudly held its top 300 feet high almost among the clouds, was tomorrow hauled down the road, unrecognizable in its altered form, after having stood the storms of probably 2000 winters. The transportation of about 762,000 feet of lumber over 14 miles of rough mountain road presented some difficulties, and about 25 four-horse teams were engaged in the work.

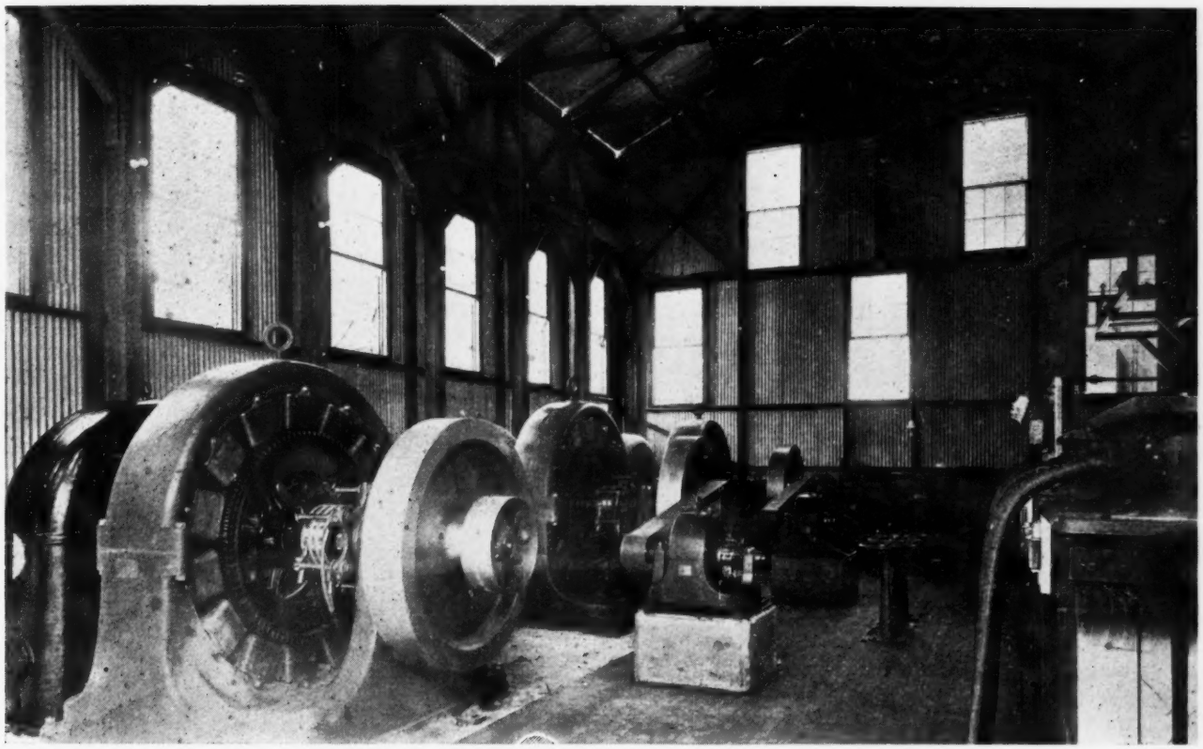
After the teams had delivered the lumber at Oak Grove it had to be gotten across the river to the flume grade, 300 feet below. This was accomplished by constructing a dry chute, in the form of a "V" flume, made by suspending two wire cables across the river and canyon from the lumber yard to the flume, and attaching thereto the V-box with adjustable rods so that the proper grade could be given the chute to carry the lumber across. This worked very successfully.

The construction of the flume was commenced at the lower end of the chute, which was only about 250 feet below the tunnel. The lumber as received was transported along on that portion of the flume already constructed, on "dollies," made especially for the purpose, to where the carpenters were working. This was continued for about 3½ miles, after which the water was turned into the completed part of the flume and the remainder of the lumber was floated to its destination. Although the lumber was freshly cut and consequently very heavy, it floated through the flume without any trouble, all predictions to the contrary notwithstanding.

The character of the ground was such that much heavy blasting had to be done to make the grade for the flume, and in many places iron pins had to be set into the rock ledges to form a footing for the posts which supported the superstructure.

THE PIPE LINE.

From the power house in a straight line to the penstock, in plain view, though 3500 feet away, was run the



NOTE THE OVERHANGING FLY-WHEELS AND WATER WHEELS.

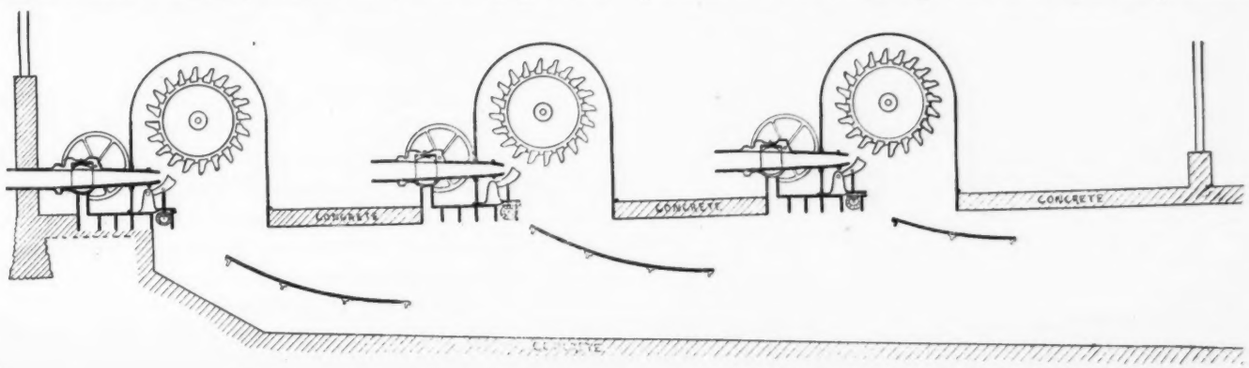
THE GENERATOR SIDE OF THE MOUNT WHITNEY POWER HOUSE.

pipe line, 1300 feet perpendicularly. It follows along on ridges the most of the way and passes down over some very steep pitches. It is securely buried in a deep trench for the greater part of the way, particularly the lower 2000 feet. The excavation of this trench alone was quite an undertaking, as much of it had to be blasted out of the solid granite, and in passing through one bluff of rocks it had to be cut 20 feet deep.

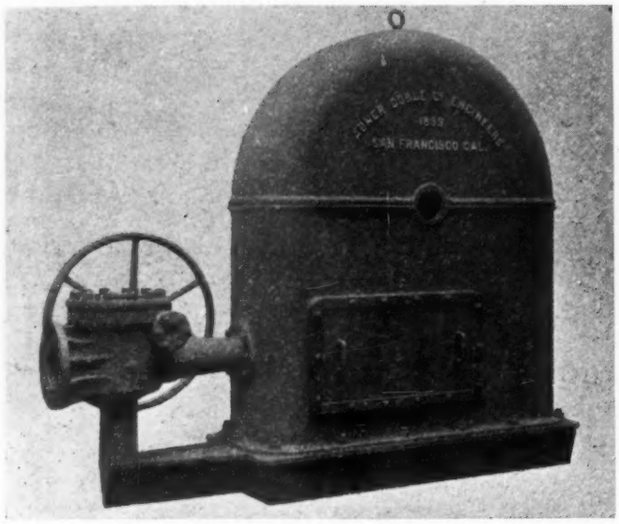
Starting at the penstock the pipe is 50 inches in diameter. It tapers down to 24 inches in the first 50 feet. This acts as a funnel and gives the water an easy entrance to the pipe. Then follows 2110 feet of riveted and 1160 feet of welded pipe as follows:

290 feet, 24 inches inside diameter, riveted steel, No. 12 gage thick; 200 feet, 24 inches inside diameter, riveted steel, No. 11 gage thick; 200 feet, 24 inches inside diameter, riveted steel, No. 10 gage thick; 100 feet, 23 inches inside diameter, riveted steel, No. 10 gage thick; 180 feet, 23 inches inside diameter, riveted steel, No. 8 gage thick; 160 feet, 23 inches inside diameter, riveted steel, No. 7 gage thick; 160 feet, 22 inches inside diameter, riveted steel, No. 5 gage thick; 180 feet, 22 inches inside diameter, riveted steel, No. 3 gage thick; 340 feet, 21 inches inside diameter, riveted steel, No. 1 gage thick; 280 feet, 20 inches inside diameter, riveted steel, No. 1 gage thick; 540 feet, 20 inches outside diameter, welded steel, $\frac{5}{16}$ inches thick; all pipe is welded below this: 200 feet, 20 inches outside diameter, steel, $\frac{11}{32}$ inches thick; 320 feet, 20 inches outside diameter, steel, $\frac{3}{8}$ inches thick; 80 feet, 20 inches outside diameter, riveted steel, $\frac{7}{16}$ inches thick; 20 feet, 20 inches outside diameter, riveted steel, $\frac{1}{2}$ inch thick.

The laying of this pipe in place was a difficult undertaking, as it had to be conveyed from the bottom of the hill up along the ditch to the proper place, lowered into position and be riveted together; this up a steep hillside,



VERTICAL SECTION OF WATER-WHEEL INSTALLATION, WITH BAFFLE-PLATES AND TAIL-RACE.

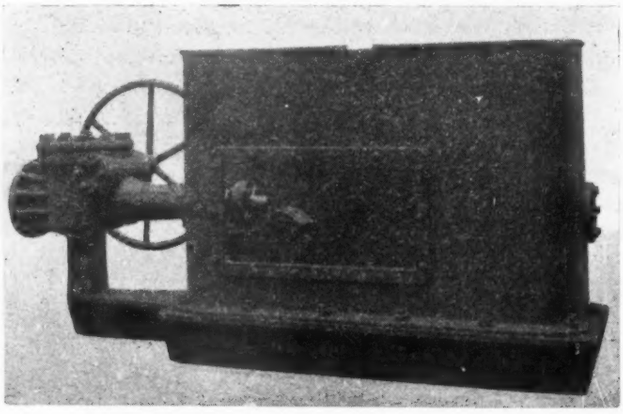


DOBLE WHEEL HOUSING AND VALVE AS USED IN THE MOUNT WHITNEY PLANT.

part of which stands at an angle of about 45 degrees and much of it at angles from 25 to 30 degrees, and over ground so undulating that more than 70 bends or angle pieces had to be made so that the pipe would conform to the profile of the ditch.

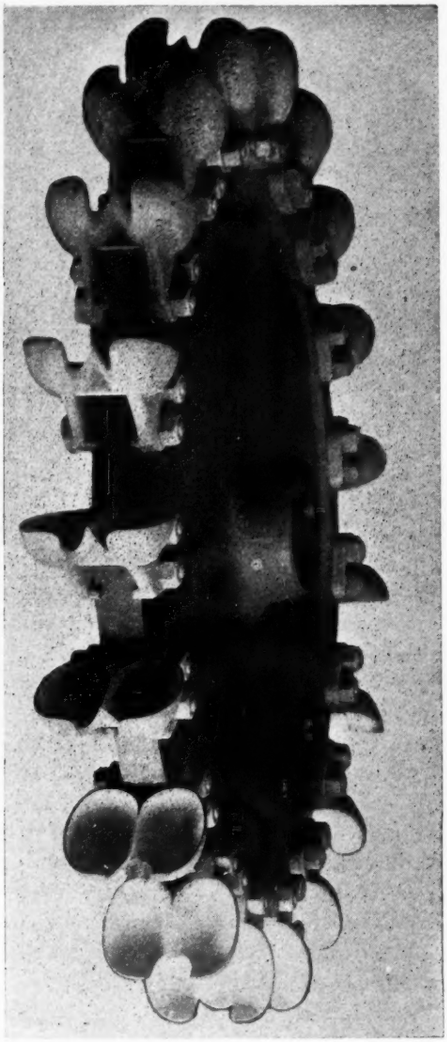
The pipe was hoisted to place by means of an overhead cable stretched from the bottom of the hill to the top, being carried on trolleys suspended from the cable and moved by means a draw line and a hoisting engine. In some places the pipe would be in the air over 60 feet on its upward journey, giving it the appearance of flying to its destination. As each joint was laid it was carefully blocked in place and the next piece entered and securely riveted, then the earth was very thoroughly tamped, with water, under and over the pipe so as to give it a perfect and solid bearing in the ditch, and then it was completely covered. At some places where the ground was favorable several pieces were riveted together before lowering into the ditch.

All of the joints were chipped and thoroughly caulked and all of the pipe well coated with asphaltum composition to prevent rusting, every care being taken throughout to secure a first-class and very substantial pipe line.



DOBLE WHEEL HOUSING SHOWING NOZZLE AND DEFLECTOR.

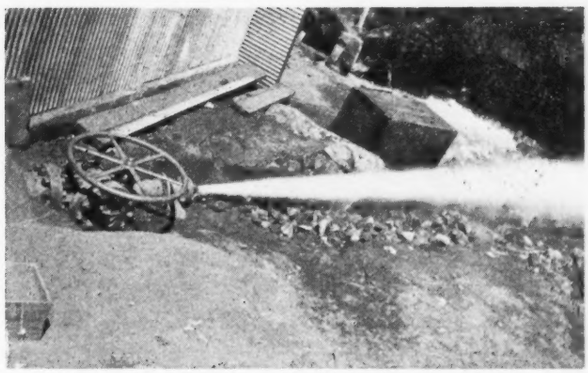
The steel plates used in making the riveted pipe were of exceptionally excellent quality, and the welded pipe the very best that could be procured. The welded pipe was put together with "bumped" joints instead of flanges, as has been done heretofore for this class of work. This improvement is a great advantage as a more secure joint can be made by riveting and the weight of the pipe is less, which is quite an item when the pipe has to be hauled 35 miles over mountain roads. For the first 400 feet from the power house the pipe was imbedded in concrete, all but the joints, and at other points where angles were



THE DOBLE ELLIPSOIDAL WATER WHEEL.

made or where the hillside was unusually steep the pipe was securely fastened to the granite bed rock by means of substantial iron bands and turn-buckle rods, and in some places concrete also was used. The pipe is provided with six air valves in the first thousand feet from the penstock. The excellence of the character of this pipe line was satisfactorily and conclusively demonstrated when it was filled and the machinery was put into motion.

At the lower end of the pipe, just at the corner of the power house building, a heavy steel casting is attached.



FOUR VIEWS OF THE MOUNT WHITNEY JET, HAVING A STATIC HEAD OF 1300 FEET, AND A 2¼-INCH NOZZLE,

It has two outlets, one entering the building and the other continuing straight ahead for ten feet, then another similar casting and then another in the next ten feet, the three outlets entering the building conveying the water to the water wheels to be described later. The fourth outlet, at the extreme end of the pipe, serves as a waste-way, and it is equipped with a gate and nozzle in all respects the same as those inside of the power house, thus affording a convenient place for testing the nozzle tips.

The pressure registered at the nozzle in the power house is 565 pounds per square inch, a pressure so great that it is hard to realize its tremendous power. A faint idea may be obtained by watching the water issuing from the waste nozzle in a stream as solid as a bar of iron, traveling at a velocity of over 17,000 feet per minute, and continuing straight across the river with such force as to strip the branches off of the trees on the opposite bank.

All of the castings and pipe at the power house are securely imbedded in concrete and are of the most substantial character.

THE POWER HOUSE.

The power house building is favorably located on the Mineral King road, near the base of Red Hill, about 35 miles from Visalia, on the south bank of the Kaweah river.

The building is a plain, though substantial structure, a framework of Oregon pine covered with galvanized corrugated iron, resting on substantial concrete foundations. It is 30x50 feet, 20 feet high at the eaves, with an addition 12 feet square. It is equipped with a hand power traveling crane of eight tons capacity, which serves to handle heavy loads in any part of the building.

The side of the building stands parallel with the pipe line and the water is led to the Doble tangential water wheels through passages of gradually decreasing area and with very easy curves, so that the increase in velocity is uniform throughout until the water issues from the tip of the nozzle. There is no receiver. The gates which close the nozzles are of special design for the great pressure in use here, and are operated by means of large handwheels through the medium of a worm and worm gear. Their construction is such that when open a uniform cylindrical aperture is presented for the passage of water so that no disturbance is set up in the flowing water.

The water wheels are of the Doble ellipsoidal type* and are solid steel castings, machine finished all over, weighing about 1400 pounds each, with 20 bronze buckets attached securely by means of two steel bolts to each bucket. The wheels are about 50 inches in diameter. There is one nozzle to each wheel and that is equipped with a special cut-off hood, operated from a stand at the switch board, so that the amount of water supplied to the wheel is at all times under the immediate control of the switch-board attendant.

A SPOUTING VELOCITY OF 17,800 FEET PER MINUTE.

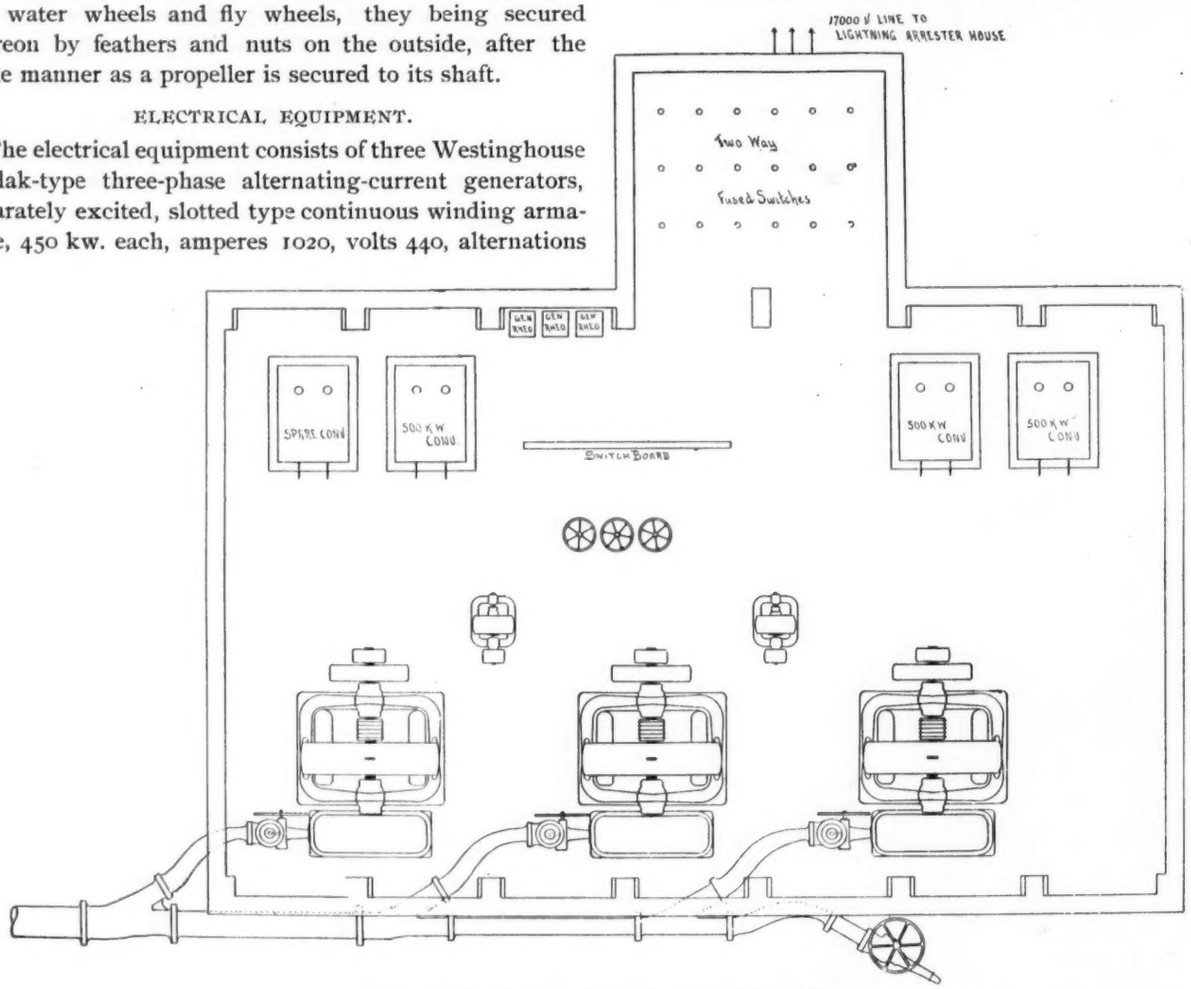
*Described in detail in the JOURNAL for October last, Vol. VIII, p. 85.

The water which is deflected downward by the cut-off device into the tail race is received upon heavy cast iron baffle plates and thence conveyed harmlessly away to the river.

The wheels are encased in heavy cast iron housings and so massive and solid is the entire hydraulic equipment that the issuing jet makes very little noise and there is no vibration in the nozzle or housing. Furthermore, the wheels are mounted directly upon the shafts of the generators overhanging the bearings. The ends of the generator shafts are turned tapering, for the reception of the water wheels and fly wheels, they being secured thereon by feathers and nuts on the outside, after the same manner as a propeller is secured to its shaft.

ELECTRICAL EQUIPMENT.

The electrical equipment consists of three Westinghouse Kodak-type three-phase alternating-current generators, separately excited, slotted type continuous winding armature, 450 kw. each, amperes 1020, volts 440, alternations



GROUND PLAN OF THE MOUNT WHITNEY POWER HOUSE.

7200, speed 515 revolutions per minute. Two bearings, the water wheels being mounted on one end of the extended shaft and a 4000-pound cast steel fly-wheel on the other end, also a driving pulley for the exciter. The weight of each generator unit is over 40,000 pounds.

The three generators give a normal capacity of 1800 horse-power. There are two belt-driven direct-current generators of 15 kw. each, for exciters, speed 1050 revolutions per minute, volts 125. Each exciter has sufficient capacity to excite the three generators, and is so located in the power house that it can be driven from either generator nearest to it.

The three generator units and the two exciters occupy the easterly half of the power house and the westerly half contains the switch board and raising transformers.

Immediately in front of the switchboard are the three stands with hand wheels for operating the cut-off hoods or deflectors on the water wheels, each one being directly opposite the panel for the generator to which it belongs.

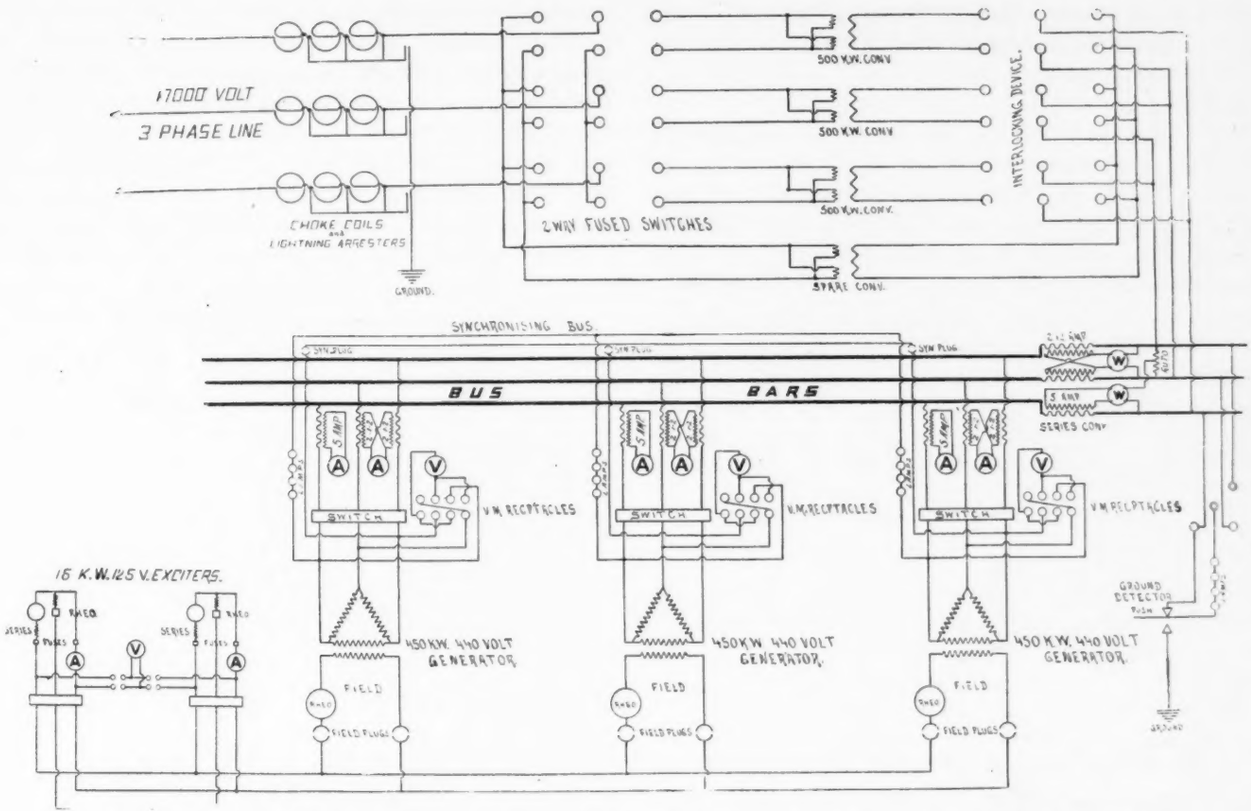
The switchboard consists of five marble panels, all 2 inches thick and 65 inches high, four of them being 24 inches wide and one 36 inches, mounted on an iron frame.

There is one exciter panel, containing two ammeters, two 3-pole single-break switches and two voltmeter plug receptacles, also pilot lamps.

There are three generator panels, each containing one voltmeter, one ammeter, one voltmeter plug receptacle, one 3-pole quick-break main switch, two field plug switches, one rheostat, synchronizer plugs and lamps and pilot lamp.

The distribution panel contains two integrating watt-meters, three quick-break double-pole double-throw main switches, with interlocking device.

From the generators and exciters all wires and cables are run under the floor in conduits to the switchboard, and from there in same manner to the raising transformers.



GENERAL WIRING SCHEME, SHOWING METHOD OF THROWING SPARE TRANSFORMER ON TO EITHER LEG OF TRANSMISSION LINE.

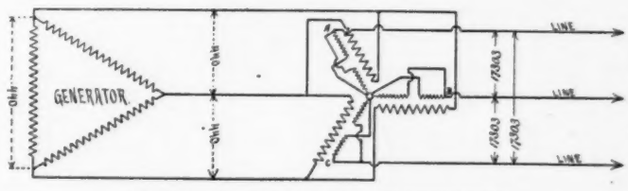
There are four raising transformers of 500 kw. capacity each, oil-insulated, air-cooled. It requires 550 gallons of mineral seal oil for each transformer. Three of the transformers will be regularly in service, the fourth one being a spare unit, but so wired at the switch board that it can be put in place of any one or the other three at once. These are three-phase transformers, primary voltage 440, secondaries divided in the middle giving 10,000 volts across terminals when connected in parallel; line voltage of 17,300; "Y" connection; when connected in series giving 20,000 volts at terminals and line voltage of 34,600. They are operating at present with coils in parallel, but are to be changed to series when the load increases.

The secondary wires lead from the top of the transformers, on brackets, to the addition on the westerly side of the power house, where the high-tension switches are arranged, by means of which the current is delivered to the transmission line.

The high-voltage current is then conducted to the lightning arrester house, a frame and corrugated iron structure about 12 feet square, located about 25 feet west from the power house. This building contains three lightning arrester units, each consisting of six choke coils in series with the line and 30 arresters mounted on a marble slab.

Thence the current is delivered onto the transmission line, consisting of three medium copper wires, No. 2 B. and S. gage, arranged in the form of an equilateral triangle, one wire being mounted at the top of the pole and the other two on a cross-arm of 3x4 Oregon pine, boiled in oil. Eucalyptus pins, also boiled in oil, are used to support the seven-inch triple-petticoated glass insulators which in turn support the transmission wires. The cross-arms are bolted to the poles and have a bolt through the ends to prevent splitting as well as to hold the pins in the arms. The top pin is secured by two nails driven through the iron band which is used to prevent the top of the pole from splitting.

About twenty-one miles from the power house the line is branched, one line going southerly through Exeter,



CONNECTIONS OF THE STEP-UP TRANSFORMERS.

Lindsay and to Porterville, the other going westerly to Visalia and thence to Tulare.

From the power house the line follows the road closely, remaining on the southerly side of the Kaweah river, through Lemon Cove to the plains where the line branches.

From the junction point to Visalia and also to Lindsay the wire is reduced in size to No. 5 B. & S. gage, and from Visalia to Tulare and from Lindsay to Porterville it is reduced to No. 6 B. & S. gage.

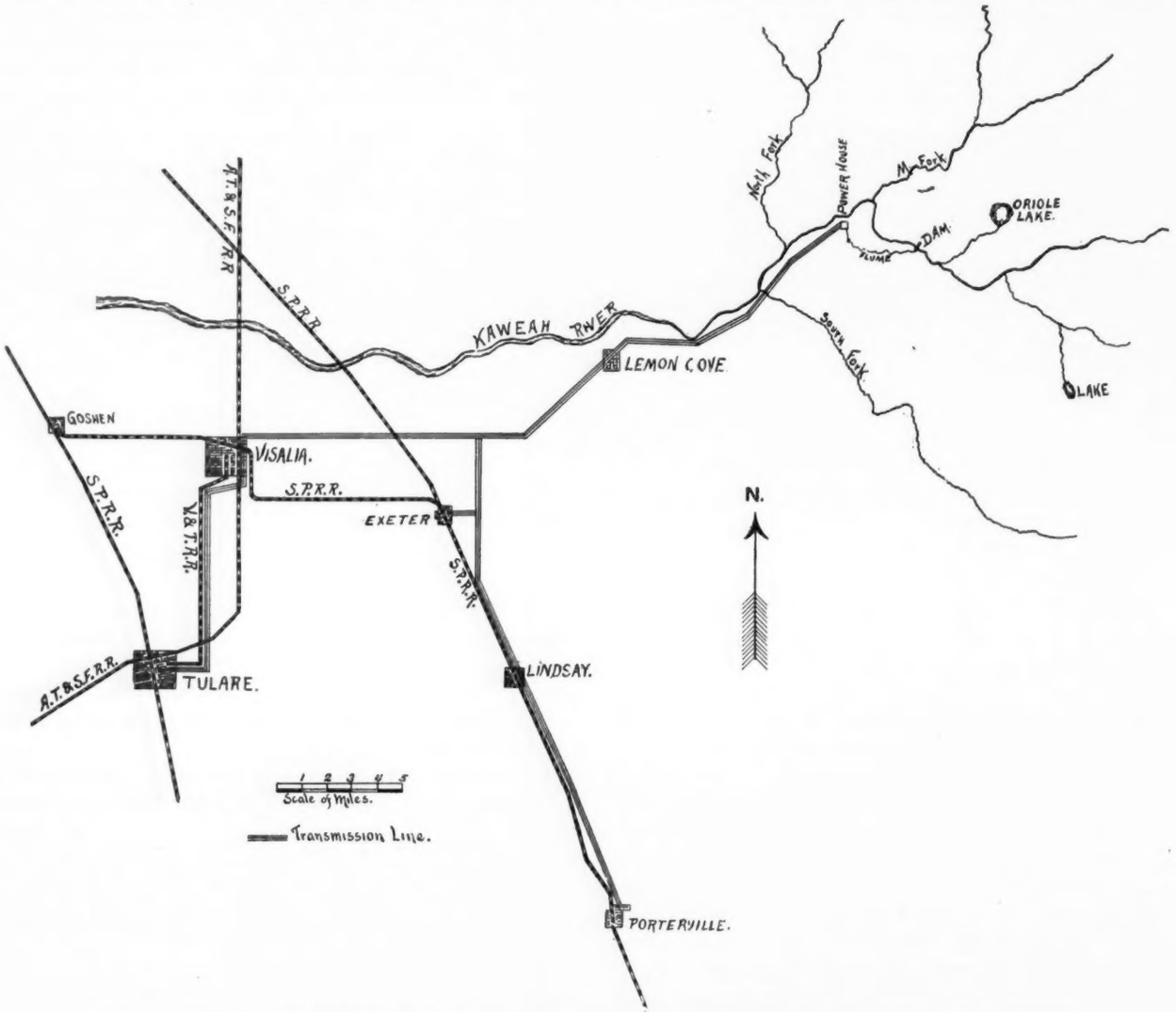
In the mountain districts the poles are 26 feet long, 5x5 at the top and 9x9 at the bottom. In the orchard dis-

tricts they are 30 feet and for road crossings and in the towns 35 and 40-foot poles are used. They are all of redwood, sawed on the northern coast.

The pole line is equipped with six-pin cross-arms, 30 inches below the power circuit, for telephone purposes. This work was done by the Sunset Telephone Company, who have a contract for the use of the poles for this purpose. A private circuit extends from the office of the company in Visalia to the power house, the other wires being for the use of the Sunset company for public business.

factory and useful, affording a ready way of changing the secondary voltage to meet the requirements caused by changes in the proportions in the loads at the various sub-stations. They are Westinghouse, oil-insulated, air-cooled type in units of 50 kilowatts and 75 kilowatts, transforming from three-phase to two-phase, two transformers therefore constituting a "bank." The distribution for light and power is at 2000 volts, two-phase current.

The Visalia station also contains a 30-light arc machine for street lighting, driven by a 20-horsepower induction



MAP OF A PORTION OF TULARE COUNTY, CAL., SHOWING TRANSMISSION LINES OF THE MOUNT WHITNEY POWER COMPANY.

Sub-stations have been established at Visalia, Tulare, Exeter, Lindsay and Porterville, each having a complete equipment of lightning arresters, high tension fused switches, step-down transformers, etc.

The primaries of these transformers are arranged with the coils divided in the middle, for parallel or series connection, same as the step-up transformers, for 15,000 or 30,000 volts (allowance being made for line drop). The secondaries have ten leads brought out, with terminal blocks, giving a range of from 1930 to 2280 volts, which is a valuable feature and has been proven to be very satis-

motor, the incandescent lighting system being supplied direct from the 2000-volt distribution and pole transformers to 104-volt secondaries. About 150 horsepower is used for lighting and about 150 horsepower more for operating induction motors in the flour mill, water works, ice works, laundry, newspaper offices, etc. The Mount Whitney company purchased and is operating the lighting system formerly operated by the Visalia Gas, Light and Heat company.

The Tulare station furnishes about 50 horsepower to operate the water works and about 40 horsepower for the

local incandescent lighting system, operated by the Tulare Gas Company.

The Lindsay station furnishes about 200 horsepower for lighting and operating pumping plants for irrigation, the electric power having superseded steam and crude oil engines for driving the centrifugal pumps. The experience with the motors has been so satisfactory that many new installations are being contracted for.

The Porterville station furnishes about 110 horsepower

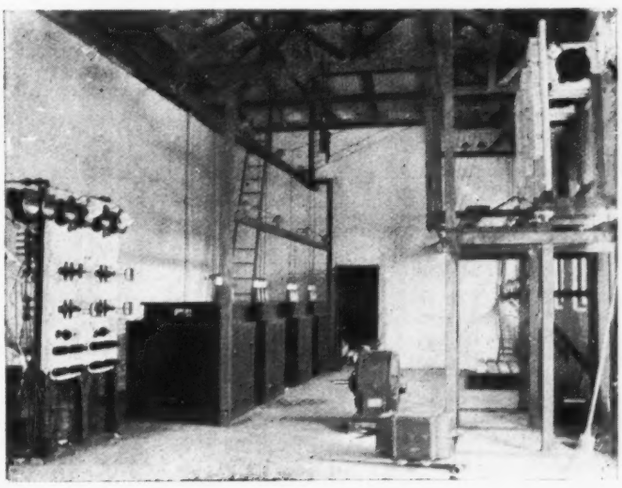
POWER HOUSE, POLE LINE AND A BIT OF THE FLUME IN UPPER RIGHT-HAND CORNER.

for lighting and power, operating an incandescent system, town water works, printing offices, hotel refrigerator, irrigating pumps, etc.

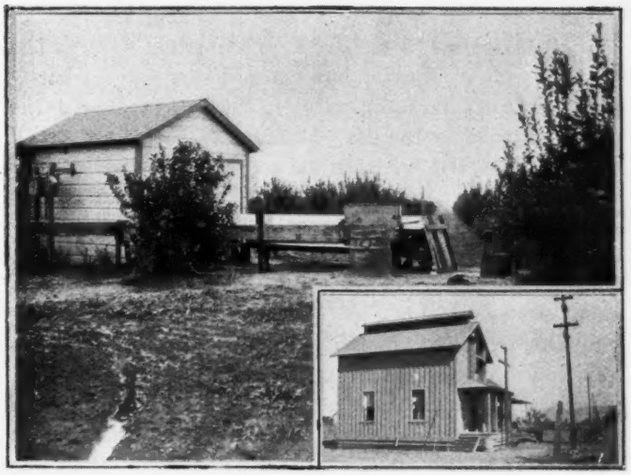
PRICE FOR POWER.

The company has fixed the very low rate of $50 per horsepower per year for the electric current, delivered to the step-down transformers of the customer on his premises, measurement by wattmeter at transformer primaries.

This low price will justify the farmer and orchardist in sinking wells and employing power to pump water. In



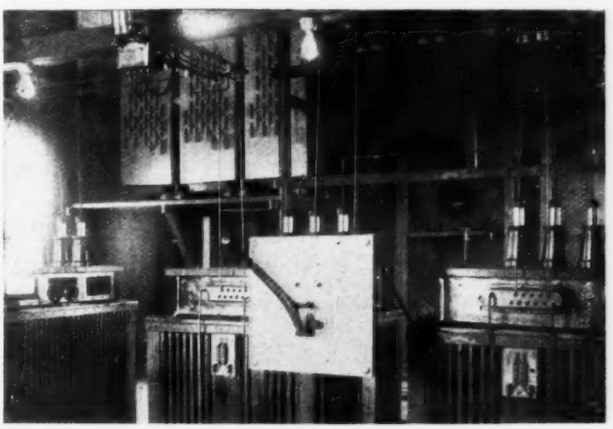
INTERIOR OF THE VISALIA SUB-STATION.



A TYPICAL PUMPING STATION IN AN ORANGE GROVE AND THE PORTERVILLE SUB-STATION.

Tulare county crop failures are unknown when there is a good rainfall, or when there is good irrigation, and obviously the man who gets a good well and a pump and uses electricity for power will free himself from lawsuits and the fear of dry seasons. That there is plenty of water close to the surface is a demonstrated fact and by using electric power it can be cheaply raised and is always ready for use.

The statements made by farmers that they only want water two or three months in the year, and by citrus fruit growers that they only want it for about five months in the year, have been proven these past to years to be incorrect. The pumping plants at Lindsay furnished water to the orange and lemon orchards from January to December, 1899, inclusive. The water right that is valuable—



INTERIOR OF A PORTION OF THE LINDSAY SUB-STATION.

that permits the farmer to grow grain, alfalfa, orchards, garden, and in fact all crops, must be permanent and available at all times. The man who gets the benefit of a constant supply of water for irrigation is never the one to complain of the cost; but on the other hand, the party who has little or no water and who pays but little for it, is very often unable to pay that little because of short crops.

Based on a supposed requirement of water for only say

five months of the year, many persons have claimed that they could operate their steam or oil engines for a less cost per annum than to pay a flat rate of $50 per horsepower per year for electricity. They also doubted the statement made by the power company that steam or oil engines could not be operated for 24 hours per day for more than five months of the year for the same cost as electric power for the entire twelve months, because they were misinformed as to the actual facts relative to cost of fuel consumed and the amount of labor required to operate oil or steam plants.

By way of comparison are given some figures as to the difference between the cost of operating steam and oil plants and electric motors. The figures are reliable, being actual results obtained from average plants operating in Tulare county; from men who have kept books on expenses and who know what they are talking about.

A certain 35-horsepower steam plant was operated at a cost of $10 per day, the cost of the electric power for one year would run this plant 175 days.

A certain 15-horsepower crude oil engine was operated at a cost of $6 per day, the cost of the electric power for one year would run this plant 125 days.

A certain 20-horsepower steam plant was operated at a cost of $5 per day, the cost of the electric power for one year would run this plant 200 days.

PERSONAL.

To Messrs. Wm. H. Hammond and A. G. Wishon of Visalia is due the credit of the inception and successful completion of this great enterprise. For years they had labored with a view to utilizing the waters of the Kaweah River for furnishing power to light the towns of Tulare county and to operate machinery for manufacturing and for pumping water. With the financial assistance of Messrs. John Hays Hammond and Leopold Hirsch of London they were enabled to carry out the project.

Mr. Wm. H. Hammond is president of the company, Mr. A. G. Wishon is vice-president and Mr. R. P. Hammond is secretary.

Mr. Robert McF. Doble, consulting engineer and Mr. D. L. Wishon, civil engineer.

Mr. A. B. Cone, superintendent of power house.

The untiring energy and application of Messrs. Hammond and Wishon, with the interest and pride taken in their work by the employees, made it possible to construct this great enterprise in the short period of about nine months from the time work was actively commenced.

It is of further interest to note that the contract for the entire electrical equipment of the Mount Whitney Power Company was secured for the Westinghouse Electric and Manufacturing Company by H. D. Scribner, one of its Pacific Coast sales agents and who forms the subject of the illustrated "personal" of this issue of the JOURNAL.

And so well was everything done, in spite of the disadvantages attendant upon a "rush" job, and the further fact that the work was in progress during the winter, the machinery started off without a hitch of any kind, and has been giving perfect service since June, 1899.

ENGINEERING DATA OF THE MOUNT WHITNEY POWER TRANSMISSION.

TUNNEL—Width, 3 feet; height, 6 feet; length, 47 feet.

FLUME—Length, 30,000 feet. Inside dimensions: width, 36 inches; depth, 22½ inches. Grade, 26.4 feet per mile. Velocity of flow, maximum, 7 feet per second. Carrying capacity, maximum, 37 cubic feet per second. Material, mountain redwood, 1½ in. thick for bottom and sides.

PENSTOCK—Depth, 16 feet; width, 6 feet; length, 8 feet. Material, mountain redwood.

PIPE LINE—Length: section A, 2110 feet; section B, 1160 feet; total, 3270 feet. Diameters: section A, 24 to 20 inches inside; section B, 20 inches outside. Thickness: section A, No. 12 to No. 1, U. S. gage; section B, $\frac{5}{16}$ to ½ inch. Material: section A, double-riveted steel; section B, lap-welded steel. (Further details of pipe will be found in body of article on preceding pages). Gradient, maximum, 36 degrees. Air valves, six. Receiver, none. Head: 1300 feet static; 1265 feet delivering 20 cubic feet per second. Velocity: with 20 cubic feet per second, maximum 9 feet; average 7.8 feet per second. Capacity: with 20 cubic feet per second, 2800 horsepower to water wheels.

Contractors: Lacy Manufacturing Company, Los Angeles, Cal.

POWER HOUSE EQUIPMENT.

HYDRAULIC—Water Wheels: Three Doble Tangential, steel centers 44 inches diameter, with 20 gun-metal buckets; speed, 514 revolutions per minute. Maximum capacity, 1000 horsepower. Mounted on the end of generator shaft. Hand regulation. Fly-wheels: Three annealed cast steel, turned all over; 50 inches diameter, 10½ inches face; weight, 4000 pounds. Mounted on end of generator shaft.

Contractors: Abner Doble Company, San Francisco.

ELECTRICAL: Generators, 3 Westinghouse, alternating, Kodak type, three-phase; armature, slotted type, continuous winding; 14 poles, separately excited; normal capacity each, 450 kilowatts, 1020 amperes, 440 volts, 515 revolutions per minute, 7200 alternations.

Transformers: Four Westinghouse oil-insulated, air-cooled; normal capacity of each, 500 kilowatts (one spare); primary electromotive force, 440 volts, three-phase; secondary, 17,300 or 34,600 volts; "Y" connection.

Lightning Arresters: Three Westinghouse units type "R," with choke coils and spark gap cylinders, mounted on marble slabs.

POLE LINE—Length: from power house to junction, 21 miles; from junction to Tulare, 20 miles; from junction to Porterville, 21 miles; total 62 miles. Size of poles: 5x5 at top, 9x9 at bottom, 26 feet long; 5x5 at top, 9x9 at bottom, 30 feet long; 5x5 at top, 10x10 at bottom, 35 feet long; 5x5 at top, 10x10 at bottom, 40 feet long; the 35 and 40 foot poles being used for road crossings,

Poles: material, coast redwood, sawed; distance apart, from power house to junction, 120 feet; remainder of line, 130 feet.

Cross-arms: material, Oregon pine; sizes, from power house to junction, 3¾x4¼x44 inches; remainder of line, 3¾x3¾x44 inches; secured to poles by two ⅝-inch bolts.

Pins: material, eucalyptus boiled in linseed oil; size, 1⅝ inches shank, 11 inches long over all.

Insulators: Locke triple-petticoat annealed glass, 7 inches diameter.

Circuits: one; wires at points of equilateral triangle with 36-in. sides; spiraling, none.

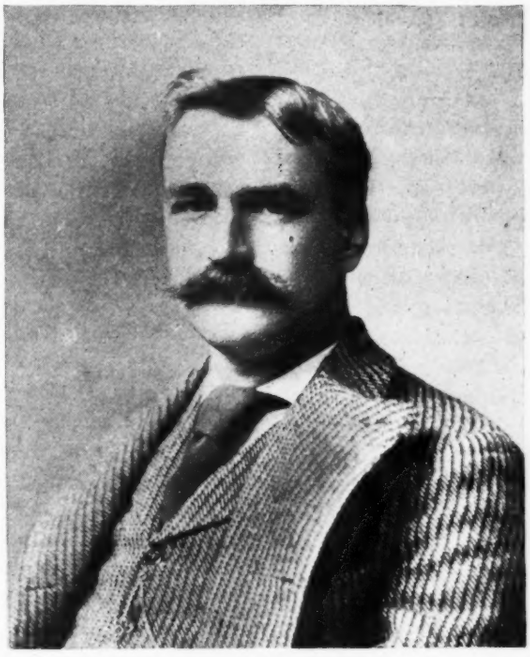
Wire: copper; from power house to junction, No. 2 B. & S. gage, 21 miles; junction to Visalia, also Lindsay, No. 5 B. & S. gage, 19 miles; Visalia to Tulare, and Lindsay to Porterville, No. 6 B. & S. gage, 22 miles.

Telephone circuit: No. 12 B. & S. gage, bimetallic.

SUB-STATIONS—Equipped with 3-phase to 2-phase lowering converters, primaries, 15,000 or 30,000 volts; secondaries, 1930 to 2280 volts in ten steps with terminals; oil-insulated, air-cooled. At Visalia, four transformers of 75 kilowatts each; at Tulare, two transformers of 75 kilowatts each; at Exeter, two transformers of 50 kilowatts each; at Lindsay, four transformers of 75 kilowatts each; at Porterville, four transformers of 50 kilowatts each; also choke-coils and lightning arresters, same as at power house. Distribution from the various sub-stations, two-phase for lighting and motor service, 2000 volts.

Personal

HERBERT D. SCRIBNER, familiarly called "Scrib" by almost every electrical man west of the Rockies, was born in the state of Maine of good old Yankee and Quaker stock, and was educated in the public schools of Lynn, Mass., after graduating from which he took a short course in engineering in the Boston Institute of Technology and in the Quaker College at Providence, R. I. After the factory of the Thomson-Houston Electric Company had been moved from New Britain, Conn., to Lynn, and before the Thomson-Houston company began the manufacture of alternating-current apparatus, "Scrib" took the expert course provided by the company, with which he remained during the early development of its railway and single-phase alternating apparatus. The first successful electric railway in the city of Boston was that runnig from Bowden Square to Arlington through Harvard Square in Cambridge, and this was erected by Mr. Scribner. This was also the first trolley line to use iron poles. It was installed for the West End Street Railway Company, and formed the nucleus of that which is now the greatest street railway system in the United States if not in the world. Shortly after this plant was put in operation, Mr. Scribner was sent west by the Thomson-Houston company, since which time he has remained on the Pacific Coast.



HERBERT D. SCRIBNER

It is now ten years since the subject of this sketch severed his connection with the Thomson-Houston company to enter the construction field, and, as electric railway work was just entering its "boom" at that time, he became prominent in its circles throughout the West. Among the street railway lines which were constructed and completed by Mr. Scribner, were the roads of the Spokane Street Railway Co., the Lidgerwood Park Electric Railway Company, and the Ross Park Electric Railway Company, all of Spokane, Wash.; the Tacoma and Steilacoom Electric Railway Company of Tacoma, Wash.; the Anacortes and Fidalgo City Railway Company, of Fidalgo Island, Wash.; the Falls City line of the Portland General Electric Company, Oregon City, Or.; the line equipment of the Oakland, San Leandro and Haywards Electric Railway Company, of Oakland, Cal.; the San Diego Street Railway Company, San Diego, Cal., and the Stockton Street Railway Company, of Stockton, Cal. After street railway construction had quieted down, Mr. Scribner entered the mining field in the West Kootenay district, in British Columbia, where he is owner of interests in valuable claims.

In 1894 he entered the employ of the Westinghouse Electric and Manufacturing Company as traveling salesman of the Pacific Coast office, which position he has held ever since. This makes him the oldest man in the continuous service of the Westinghouse company on the Pacific Coast. At present, most of his time is devoted to the sale of polyphase apparatus for use in electric power transmission work, and it is a gratification alike to him, to his friends and to his patrons, to know that he is reaping an abundant harvest in this particular direction alone. The contracts for some of the most notable transmissions in the West were secured for the Westinghouse company by Mr. Scribner, among which is prominently that of the Mount Whitney Power Company, of Visalia, Cal., which forms the subject of the principal article of this issue. To meet "Scrib" is to like him; to know him is to admire him, and to be on terms of intimacy with him is a most wholesome privilege, be it viewed from either a personal or a business standpoint. As a consequence, his innumerable friends are found all over the Pacific Coast from Alaska to old Mexico, all of which is very agreeable personally, and very profitable commercially, to the company which is so fortunate as to possess his services.

F. A. C. PERRINE, D. Sc., has resigned from the professorship of electrical engineering for the Leland Stanford Junior University, as well as from the electrical engineership of the Standard Electric Company of California, and, about February 1st, will return to the East where he will remain hereafter. Dr. Perrine has accepted a position of trust and responsibility with the Stanley Electric Manufacturing Company of New Jersey, a new concern incorporated on January 5th, and which is to absorb the Stanley Electric Manufacturing Company of Pittsfield, Mass. This new corporation is backed by the Roeblings and other equally influential interests.

JOSEPH E. GREEN has resigned the managership of the electric department of the San Francisco Gas and Electric Company and has become identified with the recently incorporated San Francisco Electric Light and Power Company and the Consolidated Light and Power Company of San Mateo and Santa Clara counties. Each of these new companies are related to the Standard Electric Company of California and are incorporated for the purpose of effecting the local distribution in San Francisco, San Mateo and Santa Clara counties of the proposed transmission from Blue Lakes to San Francisco. Mr. Green's name appears as a director in each of the new concerns.

R. J. DAVIS has resigned from his former position as assistant manager of the electrical department of the San Francisco Gas and Electric Company and will henceforth devote his time to the many important interests with which he is associated, among which are the American Balance Slide Valve Company, of San Francisco and Jersey Shore, Pa., the Electrical Engineering Company, of San Francisco, of both of which companies he is president, and the Consolidated Light and Power Company of San Mateo and Santa Clara counties, of which he is a director.

EDWARD P. BURCH, electrical engineer for the Twin City Rapid Transit Company, of Minneapolis, has resigned his position with the company to become a consulting engineer. Mr. Burch has been the company's chief electrician for nearly eight years. Among more recent work he has installed and supervised the op-

(Continued on page 23.)

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EDITORIAL.

THE MOUNT WHITNEY PLANT.

Although electric power transmission is now fairly well settled down to defined practices, yet each new plant brings out new features, some of which, as individualities, are specific to the plant itself, while the majority of them form really important additions to knowledge concerning such installations. Fairly conspicuous in this regard is the new electric transmission of the Mount Whitney Power Company, forming the subject of the leading article of this issue of the JOURNAL, and which is now authentically and exhaustively described for the first time.

The Mount Whitney transmission presents an example of a carefully worked-out commercial proposition rather than a specimen of brilliant and striking engineering. It has no startling innovations, no pet theories have been pandered to, and all—but no more—has been done that was necessary to erect a thoroughly substantial and reliable transmission whose work should primarily consist in the pumping of water for irrigation purposes.

Aside from the high head used, the fact that it is the first large elecrtic transmission plant to be equipped with ellipsoidal water wheels, and the emphasis it places on the influences which irrigation is extending on the development of electric power transmissions, the Mount Whitney plant is noteworthy mainly for the silent but convincing testimony it bears to the correctness of the idea of mounting water wheel, armature and fly-wheel on a single set of bearings—that is, with overhanging water wheel and fly-wheel. This type of construction was initially installed in the Blue Lakes power house where it gave continuous and most satisfactory service until the destruction of the plant by fire in November last, thus disproving the contentions of many engineers and manufacturing concerns of prominence, some of whom declined to countenance overhanging bearings under any consideration. The splendid success which has attended the operation of this type of mountings in the Mount Whitney plant as well as in the Blue Lakes power house, seems to warrant the prediction that overhanging bearings are destined to take an important part in electric transmission practice. Another feature of the Mount Whitney transmission that seems worthy of emulation is found in the absence of a receiver for the pipe line, and the designing of the pipe line so that the water shall be taken along easy lines and curves, with constantly increasing acceleration.

From a strictly electrical standpoint, the chief novelty rests in the means adopted for throwing a spare transformer into service in the event that either of the raising transformers at the power house becomes disabled. This involves the throwing of both primary and secondary switches of the step-up transformer after the manner so clearly presented in the text and diagrams of the article referred to, and the operation may be so quickly performed that the burning out of a raising transformer and the cutting in of the spare unit in its place, need not interrupt the service even when fully loaded, for the reason that the two transformers which remained intact will carry the three-phase load on the line, albeit that the transformers are overloaded, until they shall have been relieved by the cutting in of the spare transformer.

It is but fitting that thanks should be extended to Mr. Robert McF. Doble for his labors in preparing so valuable a contribution to transmission literature as is found in the article referred to.

A REMARKABLE SYNCHRONIZING TEST.

Professor S. P. Thompson in his inaugural address as President of the Institution of Electrical Engineers, London, November 16, 1899, reminded those present that in the working of alternate-current generating stations, where parallel running of a number of generators is a necessity, the station engineer has always before him the fear of a serious breakdown should anything happen to one of the generators. If the field magnet of any one generator loses its magnetism through any failure of the exciting current then all the other generators instantly pour an immense current through its armature, with dire disaster not only to it but to the station as a whole.

All manner of devices have been designed to combat this dread eventuality. Fuses and safety devices of every description, including automatic disconnecting gear warranted to operate only for currents in opposition of phase, are found not always to do their duty. Much discussion has arisen as to whether the excitation of alternators in parallel ought to be an excitation in parallel, or whether each alternator ought to be provided with a separate exciter on its own shaft. Even excitation in duplicate from two independent sources has been tried. It is satisfactory to note that a means has been discovered which will entirely remove this source of anxiety and render such accidents impossible in the future.

Professor Thompson then narrated a test described in a recent number of a French electro-technical publication*

*Bulletin de la Societe Internationale des Electriciens, p. 498, December, 1898.

upon two alternators of 250 kilowatts each, direct-driven at 67 revolutions per minute by two horizontal compound engines, the alternators being built by Farcot. Both alternators were seperately excited and were synchronized together and put in parallel in the usual manner. While thus running, the excitation was suddenly cut off from the field magnets of one alternator, and then the steam was cut off from the engine of the other alternator, which remained excited. Both machines continued to turn, the unexcited alternator continuing the supply, furnishing current for the lighting circuit and also supplying enough current to continue to drive, at nearly normal speed, the other machine and its engine.

This extraordinary test, repeated many times, took place in the lighting station of the town of St. Ouen. The explanation lies in the construction of the alternators. Their revolving field magnets are furnished on the plan suggested by M. Leblanc with the device termed by him an *amortisseur*, which is nothing else than a simple and substantial squirrel cage of copper embedded in the pole pieces of the field magnets, each pole being perforated with six slots to receive six stout copper rods, the whole of which are short-circuited by two external rings of copper.

We are all familiar with the device introduced by Dobrowolsky and Brown nearly ten years ago into the so-called rotors of polyphase motors. In these motors the squirrel cage structure revolves at a slightly lower speed than that of the revolving magnetic field; and it has been long known that if the same structure is mechanically caused to revolve at a speed slightly above sychronism, the machine becomes a generator taking power to drive it. It should, perhaps, be brought out more strongly that the induction motor must be first connected to a source of current supply and then be brought up above synchronism therewith before it will act as a generator wnen driven above synchronous speed by exterior mechanical means. In this instance, the exciting current for the motor is taken from the external source of supply. In brief, the induced eddy currents in the copper structure of the rotor, when revolved above or below synchronism, magnetize it and make it act as a field magnet. Leblanc, adapting this device to the actual field magnets of alternators, has not only simplified the operation of synchronizing, but has given to the alternator the new and remarkable property that, on the failure of the excitation from the ordinary source, the automatic action of the eddy current comes into play and thereby prevents the disastrous reactions which have been so much dreaded by station engineers. Prof. Thompson regards this invention as one of the most important of recent years. It has been applied also to the 600-kilowatt alternators in the sector of the Champs Elysees in Paris.

The Hutin and Leblanc *circuits amortisseur*, or "damping circuits," is discussed by a correspondent of a London electrical journal,* who further describes the device as consisting essentially of any closed circuits so placed that the alternating current in the armature can induce eddy currents in them. The scheme, therefore, bears more than a close resemblance to the damping rings placed on the poles of rotary converters to prevent "pumping" when two or more rotaries are run in parallel. In the present instance, however, the poles of an alternator having solid in place of the usual laminated pole-pieces, fulfill the condition of inducing eddy currents to a certain extent, but since only those eddy currents which flow in a direction parallel to the armature conductors are fully effective in the way about to be explained, Leblanc confines them all to that direction by making the poles laminated and placing a number of solid copper bars in slots or holes just within the polar face and connecting them all together at the ends by two massive copper rings. The number and size of the bars is not of much importance, as the effect is almost the same whether a few bars be used, the total weight of copper remaining the same. Leblanc uses about one and a half to two times as much copper in the *amortisseur* winding as in the main armature winding. This can be done without increasing the cost of the machine greatly, as the weight of armature copper is not usually a serious item.

The action of the device is complicated, though perhaps it may be understood sufficiently from the following: Suppose that two alternators are running in parallel and that from some cause one of them slows down slightly. The magnets of the slow machine will now be cutting the pulsating flux, which exists opposite each armature coil, due to the alternations of the armature current. The rate at which this cutting goes on is equal to the difference between the periodicity of the armature current and the number of magnet poles manipulated by the number of revolutions of the magnets per minute divided by 120. This will induce heavy eddy currents in the *amortisseur* winding, which will, just as in the case of the ordinary squirrel-cage non-synchronous motor, produce a drag on the magnets, tending to bring them up to synchronous speed again, and so distinctly reducing the likelihood of the machines falling out of step. The same self-righting effect occurs, of course, when the speed of one engine rises above that of the other. This property of the *amortisseur* makes it unnecessary to be very particular about getting the speeds of the two alternators exactly alike before switching them into parallel.

In the case of the particular test mentioned above by Prof. Thompson, *viz.*, two alternators running in parallel and the excitation suddenly cut off from one of them, while at the same time steam is cut off from the engine of the other alternator, the action is somewhat as follows: The speed of the excited machine, which has the engine giving no power, falls slightly below synchronism. Eddy currents are induced in the *amortisseur* by the cutting of the flux produced opposite each armature coil by the armature current. The interaction between the armature current and the eddy currents keeps the magnets on

The Electrical Engineer, Vol. XXIV., No. 26, p. 826; December 29, 1899.

the revolving field in rotation. The magnets, being fully excited, induce almost the normal voltage in the armature winding. At the same time the magnets of the unexcited alternator will be running at a speed slightly above that of synchronism. Eddy currents are induced in the *amortisseur*, which magnetize the magnets in such a way that the machine acts as a generator, supplying current both for the lighting and for driving the other alternator with its engine. The current required for this last purpose would probably be considerably in excess of the normal full load of the machine, so that the overload which has to be carried by the armature of the other alternator is very great. Even if steam were left fully on both engines the result would be much the same, because unless the engines were specially well governed, the fact that a heavy overload was being generated by one machine and very little load by the other, would cause the necessary difference in speed between the two machines. The use of an *amortisseur* winding slightly decreases the efficiency of the alternator, as even when not running in parallel with other machines there is always a certain amount of eddy current loss going on in it.

Benischke states* that the very effective damping of the amplitude of oscillation which is accomplished by Leblanc's *amortisseur* is entirely analogous to that of Waltenhofen's pendulum, consisting of a copper plate, the oscillations of which are damped at once by eddy currents induced in it when cutting through a magnetic field.

Gas

INDUSTRIAL GAS.—X.

BY FRANK H. BATES.

[THE JUNKER CALORIMETER—CONTINUED.]

ORDER of observation of temperatures. The following order of observations of temperatures may be observed:

1. *Temperature of the room* as read from a thermometer suspended close by. This gives the temperature of the air entering the calorimeter for the combustion of the gas. The temperature of the room should, if possible, be kept fairly constant, thus obviating the necessity of taking many readings, simply having the observations made at regular intervals and sufficiently often to give a fair average. It will generally be found convenient to make the readings at the beginning, middle and end of each test, when the temperature can be maintained fairly constant.

2. *Temperature of the gas leaving the meter*, read from thermometer G (Figure 27, December issue). The same remarks apply regarding the frequency of these readings as for the preceding.

3. *Temperatures of the exhausting products of combustion*, read from the thermometer at J. The same remarks apply here. The readings 1, 2 and 3 may therefore be taken together with the same intervals of time.

4. *Temperature of the water entering the calorimeter* as read from the thermometer F. These readings should be taken at intervals of about thirty seconds, with tests of, say, some six minutes duration.

5. *Temperature of the heated water leaving the calorimeter*, as read from the thermometer at F'. This reading should be taken simultaneously with, or immediately after No. 4.

Starting and ending of the tests. Have everything in operation, the heated water from the calorimeter flowing into the drain, and with the temperatures of the inflowing and outflowing waters fairly constant, then, just previous to commencing the test, set down on a blank prepared for this purpose the temperatures 1, 2 and 3. Now take the rubber tube attached to the heated water outlet C, in the left hand, and, having the large graduate (empty) close by, wait until the hand on the meter dial has reached a convenient starting point, when place the rubber tube in the graduate that the heated water may be collected. As quickly as possible note the readings 4 and 5 of the thermometers F and F' and the time by an open watch, making record of all, including the meter reading, on the blank. Continue the readings at the intervals stated, taking notice that the water in the graduate does not get too l igh and that the meter continues to register.

To make certain of the continued ignition of the gas at the burner tip, it will be found convenient to employ a small mirror to be placed on the table below the combustion chamber of the calorimeter so as to reflect to the eye the condition of the flame above.

On the water reaching the 1700-cubic centimeter mark on the graduate, make ready to consider the next as the final reading, and immediately after taking the readings 1, 2, 3, 4 and 5, transfer the rubber tube from the graduate to the drain, at the same instant noting the reading of the gas meter.

Derivation of results. The form given herewith shows an arrangement for tabulating the temperatures and the final results. Under the heading "observations" are written the various measurements with their corresponding symbols for use in the subsequent derivation of results. The times of but the first and last readings are given, but if desirable may be inserted for all.

Beneath are found the averages of the foregoing readings and the total amounts of gas used and water collected. With the two tests given no note has been made of the water of condensation; this will be taken up later.

With the two tests tabulated, there was an intermission of some five minutes.

The results are carried out independently and should afterwards be averaged for a final value.

Throughout the form given the readings and determinations are entirely in the French system, the final results being then converted into the English. If preferable, all parts of the apparatus may be secured with English graduations, enabling the operator to make the computations directly in British thermal units per cubic foot or per pound.

Under the heading "uncorrected calorific value of" is

*Elek. Zeit., December 14, 1899.

DETERMINATION OF THE CALORIFIC POWER OF.....COAL GAS

Date..... | *Locality*..... | *Notes*.....

No. 1..... | ..... | .....

OBSERVATIONS.

	Temperature of Room Degrees Centigrade	Temperature of Gas Degrees Centigrade	Temp'ture of Exhaust Gases Deg. Cent.	Temperature of Inlet Water Deg. Cent.	Temperature of Outlet Water Deg. Cent.	Liters of Gas by Meter	Liters of Water Collected	Cubic Centimeters of Water of Condensation	NUMBER OF READINGS	TIME OF READINGS
Symbol or Formula...	T_R	T_G	T_{EG}	T_{IW}	T_{OW}	G	W	Wc		
	26.1	25.6	20.	14.75	29.75				1	8h. 15' 0" P. M.
				14.75	29.78				2	
				14.75	29.78				3	
				14.75	29.79				4	
				14.75	29.79				5	
	26.1	25.6	20.	14.75	29.78				6	
				14.75	29.75				7	
				14.74	29.74				8	
				14.72	29.72				9	
				14.72	29.73				10	
				14.72	29.75				11	
	26.1	25.6	20.	14.72	29.76				12	8h. 20' 30" P. M.
Average of Readings..	26.1°	25.6°	20.0°	14.739°	29.76°	Total 4.5	Total 1.740	Total		

DETERMINATION OF THE CALORIFIC POWER OF.....COAL GAS

Date..... | *Locality*..... | *Notes*.....

No. 2..... | ..... | .....

OBSERVATIONS.

	Temperature of Room Degrees Centigrade	Temperature of Gas Degrees Centigrade	Temp'ture of Exhaust Gases Deg. Cent.	Temperature of Inlet Water Deg. Cent.	Temperature of Outlet Water Deg. Cent.	Liters of Gas by Meter	Liters of Water Collected	Cubic Centimeters of Water of Condensation	NUMBER OF READINGS	TIME OF READINGS
Symbol or Formula...	T_R	T_G	T_{EG}	T_{IW}	T_{OW}	G	W	Wc		
	26.1	25.6	20.	14.72	29.58				1	8h. 25' 0" P. M.
				14.72	29.58				2	
				14.72	29.58				3	
				14.72	29.58				4	
				14.72	29.58				5	
	26.1	25.6	20.	14.73	29.59				6	
				14.75	29.61				7	
				14.75	29.63				8	
				14.78	29.63				9	
				14.78	29.60				10	
				14.78	29.60				11	
	26.1	25.6	20.	14.78	29.60				12	8h. 30' 30" P. M.
Average of Readings..	26.1°	25.6°	20.0°	14.7458 deg's.	29.5966 deg's.	Total 4.5	Total 1.755	Total		

CORRECTIONS AND DERIVED RESULTS.

Uncorrected Calorific Value of.....*Gas.*

NAME OF UNITS.	SYMBOL	FORMULA		NUMBER OF UNITS	
		HIGH = H	LOW = L	HIGH	LOW
Calories per Cubic Meter	C	$\frac{W \times (T_{OW} - T_{IW}) \times 1000}{G}$	$C_H - \left(\frac{0.6 W_c \times 1000}{G}\right)$	5808.1200 5791.8120	
British Thermal Units per Cubic Foot	B	$C_H \times 0.11236$	$C_L \times 0.11236$	652.60036 650.76799	

Correction Constants of.....*Gas.*

K CORRECTION CONSTANT FOR $T_{IW}-T_G$			K′ CORRECTION CONSTANT FOR $T_{EG}-T_{IW}$		
KIND OF GAS	SYMBOL	VALUE	KIND OF GAS	SYMBOL	VALUE
Average Natural Gas	K_N	0.011 C. 0.025 B. T. U.	Average Natural Gas	K'_N	3.432 C. 7.567 B. T. U.
Average Coal Gas	K_C	0.010 C. 0.023 B. T. U.	Average Coal Gas.....	K'_C	2.466 C. 5.437 B. T. U.
Average Water Gas.....	K_W	0.009 C. 0.020 B. T. U.	Average Water Gas.....	K'_W	1.353 C. 2.983 B. T. U.
Average Producer Gas....	K_P	0.0089 C. 0.019 B. T. U.	Average Producer Gas....	K'_P	0.470 C. 1.037 B. T. U.

Corrected Final Values of.....*Gas.*

NAME	SYMBOL	FORMULA	NUMBER OF UNITS
Calories p'r cubic meter.....	C_K	$\frac{W \times (T_{OW} - T_{IW}) \times 1000 + K(T_{IW} - T_G) + K'(T_{EG} - T_{IW})}{G}$	5820.9850 5804.7688
Calories p'r cubic meter with gas measured at 0° Cent.....	C_{KR}	$C_K \times \frac{273 + T_G}{273}$	6344.8736 6327.1979
B. T. U. per cubic foot with gas measured at 0° F...	B_{KR}	$C_{KR} \times 0.11236$	712.9099 710.9239

Remarks:

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found a column termed "name of units" with calories per cubic meter designated by C, and British thermal units per cubic foot designated by symbol B. The high values of the first are derived from the formula:

$$\frac{W\ (T_{OW} - T_{IW})\ 1000}{G} \text{ in which}$$

W = liters of water collected;

$T_{OW} - T_{IW}$ = the difference in temperature of the inlet and outlet water = degrees Centigrade of rise in temperature due to the combustion of the gas;

G = liters of gas used.

Now, W ($T_{OW} - T_{IW}$) = calories of heat,

since, 1 liter of water weighs 1 kilogramme, and 1 calorie equals 1 kilogramme of water raised 1° Centigrade; consequently, in the above we have liters of water, the equivalent of kilogrammes, times degrees Centigrade, giving the number of calories for the total number of liters of gas used. Dividing then by G, the number of liters of gas, we determine the calories per 1 liter of gas, and multiplying this result by 1000 (since 1 liter = 1 cubic decimeter = $\frac{1}{1000}$ cubic meter) we have the calories per 1 cubic meter. Substituting the values tabulated we have

$$\frac{W\ (T_{OW} - T_{IW})\ 1000}{G} = \frac{1.740\ (29.76 - 14.739)\ 1000}{4.5} = 5808.12$$

and in the second test

$$\frac{W\ (T_{OW} - T_{IW})\ 1000}{G} = \frac{1.755\ (29.5966 - 14.7458)\ 1000}{4.5} = 5791.812$$

as the number of calories per 1 cubic meter. By now multiplying each of these values (designated by C_H in the formula) by the constant 0.11236 (see Table X) we determine the corresponding value in British thermal units per cubic foot, thus:

$$5808.12 \times 0.11236 = 652.60036 \text{ and}$$

$$5791.812 \times 0.11236 = 650.76799$$

These represent the heating values, uncorrected, for the temperatures of the gas, water and air, for a cubic foot of gas measured at the temperatures of T_G, 25.6° Centigrade in both tests. For purposes of comparison it is customary to reduce this value to the value at standard conditions of temperature: 0° Centigrade. We have, then, several corrections to make.

The values of the correction constants are given for $T_{IW} - T_G$ (difference in temperature of the inlet water and the gas leaving the meter) and for $T_{EG} - T_{IW}$ (difference in temperature of the exhaust gases and the inlet water). These correction constants have been calculated by the writer from the specific heats of the gases for four average kinds: natural, coal, water and producer. A slight variance in composition, such as is met with in these classes, will scarcely affect the accuracy of the results; and when a gas is made up of more than one class, the correction constant may be changed according to the percentages of each. The application of the correction constants is clearly shown by the formula

$$\frac{W\ (T_{OW} - T_{IW})\ 1000 + K\ (T_{IW} - T_G) + K'\ (T_{EG} - T_{IW})}{G}$$

Substituting the values of the tests given, we would have for the first:

$$\frac{1.740\ (29.76 - 14.739)\ 1000 + .01\ (14.739 - 25.6) + 2.466\ (20.0° - 14.739°)}{4.5}$$

= 5820.985 calories per cubic meter; and for the second:

$$\frac{1.755\ (29.5966° - 14.7458°)\ 1000 + \cdot 01\ (14.7458° - 25.6°) + 2.466\ (20.0° - 14.7458)}{4.5}$$

= 5804.7688 calories per cubic meter.

We have now to reduce these values to standard conditiors of temperature; that is, to determine the heating value at 0° Centigrade.

In previous articles it has been shown that the volume of a gas varies directly as the absolute temperature, or 1 cubic meter of gas measured at, say, 25.6° Centigrade, would be considerably less at standard temperature or 0° Centigrade. The values above, 5820.985 and 5804.7688, would, therefore, be the calorific values of but a fraction of 1 cubic meter of gas measured at 0° Centigrade, in consequence of which 1 cubic meter would have an increased value.

If we let

V_O = the gas volume at 0° C.,

V_T = the gas volume at T° C.,

then $V_O : V_T :: 273°\text{ C.} : 273°\text{ C.} + T°\text{ C.}$;

$$\text{or, } V_O = V_T \frac{273}{273 + T}$$

substituting in the last our values of volume and temperature (V_T = 1 and T = 25.6° C.) we would have

$$V_O = 1 \frac{273}{273 + 25.6} = \frac{273}{298.6} \text{ cubic meter.}$$

We have already determined the calorific values for this volume of gas to be 5820.9850 calories and 5804.7688 calories respectively for the two tests, but as these values are for but a fraction of a cubic meter $\left(\frac{273}{298.6}\right)$ they would be for 1 cubic meter

$$\frac{5820.9850}{273} \times 298.6 = 6344.8736 \text{ calories; and}$$

$$\frac{5804.7688}{273} \times 298.6 = 6327.1979 \text{ calories}$$

The application of the preceding operations, which are but explanatory, is given in a more concise form as shown:

$$C_{KR} = C_K \times \frac{273 + T_G}{273}$$

in which C_{KR} = the true calorific value of 1 cubic meter of the gas measured at 0° C.;

C_K = the true calorific value of 1 cubic meter of the gas measured at the temperature of T_G; and

T_G = the temperature of the gas at the meter.

The calories per cubic meter multiplied by the constant 0.11236 gives the British thermal units per cubic foot

$$6344.8736 \times 0.11236 = 712.9099, \text{ and}$$

$$6327.1979 \times 0.11236 = 710.9239, \text{ and}$$

$$\frac{712.9099 + 710.9239}{2} = 711.9169 \text{ British thermal units}$$

per cubic foot of gas, giving the average value of the two tests.

Low calorific value.

$$\underset{\text{1 kilo hydrogen}}{H} + \underset{\text{8 kilos oxygen}}{O_{\frac{1}{2}}} = \underset{\text{9 kilos water}}{\tfrac{1}{2}H_2O}$$

1 kilogramme of hydrogen uniting with 8 kilogrammes of oxygen to form 9 kilogrammes of steam at 100° C. develops 28,732 calories; whereas 1 kilogramme of hydrogen uniting with 8 kilogrammes of oxygen to form 9 kilogrammes of water at 0° C., develops 34,462 calories. The first is termed the low heat value of hydrogen, and is that which would be utilized if our gaseous fuel was used in such a way as to permit of the escape of the resulting product of combustion in a vaporized condition (steam). In the high value the latent heat of steam produced by the combustion of the gas, is included. This steam, resulting from the combustion of the hydrogen contained in the gas consumed, is condensed in the tubes of the calorimeter and escapes by way of the small pipe *d* or 35, Figures 27 and 28.

The difference between the high and the low heat values is often considerable, sometimes as great as ten per cent. When only the low heat value of a gas can be utilized its value may be readily ascertained by collecting the water of condensation flowing from the small pipe *d*, or 35, and correcting the calculated high value by deducting 0.636 calories for each 1 cubic centimeter of water so collected. This will be clear from the following:

34,462 (high heat value in calories of 1 kilogramme of hydrogen burning to 9 kilogrammes of water at 0° C.)

− 28,732 (low heat value in calories of 1 kilogramme of hydrogen burning to 9 kilogrammes of steam at 100° C.)

= 5730 calories (difference between the high and low heat values), and

$\frac{5730}{9}$ = 636. calories = the difference in calories for each kilogramme (or each liter, or each 1000 cubic centimeters) of water formed.

Consequently, for each 1 cubic centimeter the correction will be $\frac{636}{1000}$ or 0.636.

As the quantity of the water of condensation is small, the correction should be applied for a large quantity of gas, including several tests.

Say some 40 liters of gas were consumed while collecting 30 cubic centimeters of water of condensation, we would have for one liter of gas $\frac{30}{40}$ cubic centimeters; this multiplied by .636 would give the calories to be deducted from the calorific value of 1 liter of gas.

$\frac{30}{40} \times .636 = .477$ calories to be subtracted.

(Continuation in next number.)

Personal

(Continued from page 17.)

eration of the electrical apparatus at the new 10,000-horsepower water power plant of the Pillsbury-Washburn Company, in Minneapolis and St. Paul. The power plant has ten 1000-horsepower direct-connected units. Power is transmitted from three to ten miles through paper-insulated underground cable by three-phase alternating currents at 3500 and 12,000 volts, and is transformed and converted at sub-stations into direct current at 600 volts for the entire railway system of Minneapolis and St. Paul. This was the first large installation of the kind. The system has been in operation over two years. Mr. Burch has established an office in Minneapolis, 1210 Guaranty Building, as a consulting electrical engineer.

FRANK E. SMITH, who for nearly two decades has been identified with the San Francisco Gas and Electric Company and its predecessors, the California Electric Light Company and the Edison Light and Power Company, severed his connection with the first-named concern on December 1st, last. Mr. Smith is one of the most proficient central-station engineers to be found on the Pacific Coast, and the fact has been already demonstrated that there will be no lack of demand for his services in expert and other independent electrical engineering capacities.

A. R. HUNTINGTON, at one time connected with the Pacific Power Company and with the Commercial Light and Power Company, San Francisco, in the capacity of chief electrician, and more recently of the electrical engineering staff of the San Francico Gas and Electric Company, has resigned from the latter position that he might accept the chief electricianship of the Consolidated Light and Power Company of San Mateo and Santa Clara counties.

C. S. KNIGHT has resigned from his position as vice-president and general manager of the Siemens & Halske Electric Company of America and will be succeeded by O. S. Lyford, Jr., formerly chief engineer of the Westinghouse Electric and Manufacturing Company, and since electrical engineer of the Siemens & Halske company. Mr. Knight will take up other work for the Whitney Syndicate in the East.

V. G. CONVERSE, the well-known electric power transmission engineer, has established an office and factory in the Imperial Power Building, Pittsburg, Pa. Mr. Converse has brought out many transmission specialties of exceptional merit which he is now manufacturing in addition to his regular practice as consulting and supervising electrical engineer.

F. G. WATERHOUSE, a brother of the inventor of the Waterhouse arc lighting system so prominently before the electrical world some years ago, has accepted the position of general manager of the electrical department of the San Francisco Gas and Electric Company, recently vacated by the resignation of J. E. Green.

C. H. PENNOVER resigned his position as chief solicitor and purchasing agent of the electrical department of the San Francisco Gas and Electric Company on January 15th to accept the managership of the newly incorporated Consolidated Light and Power Company of San Mateo and Santa Clara counties.

G. IRVING KINNEY, formerly of the San Diego Gas and Electric Light Company, and more recently of the engineering corps of the San Francisco Gas and Electric Company, has been promoted to the position recently vacated by the resignation of C. H. Pennoyer.

ELECTRICAL RESONANCE.

ELECTRICAL resonance is defined by Dr. Louis Bell* as being substantially the same sort of thing as it is in acoustics—a strengthening of the intensity (*i. e.*, voltage) of certain vibrations when they are in tune with things subject to the same vibrations and in electrical circuit with them.

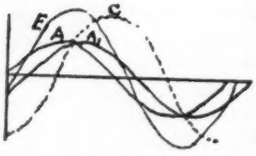
An alternating current involves electrical oscillations as complex as the vibrations of a violin string, and the resonance may take place with the main or primary vibration period, commonly called the fundamental period, or with any of the harmonics. Electrical resonance with the fundamental periodicity is rare—very rare, in fact; but the minor sort of resonance, with the higher harmonics, is probably far more common than is usually supposed.

**Cassier's Magazine*, Vol. XVII, page 132, December, 1899.

Operation

RUNNING ALTERNATORS IN SERIES.

MESSRS. Gardner and Howgrave-Graham thus explain* why it is impossible to operate alternators in series. Given two alternators which have equal electromotive forces and frequency, let the curves A and A_1 represent the electromotive force waves of the two alternators with their armatures connected in series, the machines being driven independently, but so as to give the same frequencies and pressures, and suppose them to be running synchronously but out of step by a small angle. The curve E is the algebraic sum of the ordinates A and A_1, and hence represents the resultant electromotive forces of the two machines. The curve C lags behind the resultant electromotive force curve E on account of self-induction. Now the total work done in the circuit equals the product of the sums of the electromotive force and current waves respectively—that is, the product of the ordinates of the curves E and C. The work done in either machine equals the product of its electromotive force curve and the total current curve C, which is, of course, equal in each machine. Since the pressure wave A_1 of the lagging machine is nearer to the curve C than that of the leading machine, it is clear that the product of its ordinates with the curve C will be larger than those of A and the curve C. Therefore the lagging machine A_1 is furnishing more work to the circuit than the leading machine A.



In practice, alternators are generally driven by separate belts or engines; hence, if connected in series with the leading machine, the lagging machine tends to slow up and lag more as it is the more heavily loaded. Clearly the more it lags the more work it supplies to the circuit, by reason of which it lags yet more, and so continues to do until the pressure waves of the two machines become in exact opposition, when the machines will be in stable equilibrium but will supply no power to the circuit. If they were started exactly in step, other conditions being propitious, they would do equal work and their operation in series would be satisfactory until some slight mechanical or electrical disturbance in either of them would cause them to fall out of step with the result described. The condition of equilibrium is, then, very unstable, which renders it impossible to run alternators in series unless they are rigidly connected on the same shaft. This is ordinarily impracticable.

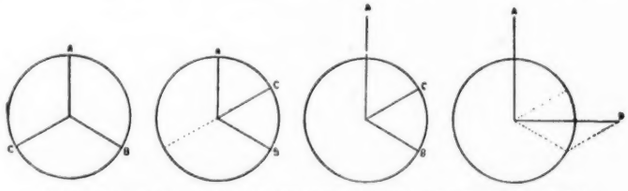
TWO TO THREE PHASE TRANSFORMATION.

CLOCK diagrams are used by P. G. Watmough† to illustrate in a very simple way the transformation of three-phase to two-phase currents. Referring to the Figure 1, A, B and C are drawn 120 degrees apart and represent the values and phase relations of a current as derived from a three-phase alternator. If now coil C be reversed, it will take the position shown in Figure 2 and the currents A, B and C therein will be 60 degrees apart. Figure 3 must be conceived as representing the magnetizing forces produced in two transformers by a three-phase current passing through the primary coils. B and C are taken as proportional to 1, and the value of A is increased to 1.73 by winding more turns on coil A. A' is therefore the value of A increased in the ratio of $\sqrt{3}$ (1.73), and as such, represents the flux in one transformer. But B and C coils are arranged so as to act together in the primary of a second transformer, and the resultant of their forces produce D, appearing in Figure 4. Finally, as the resultant D may be geometrically proved to be equal to and at right angles with A', two-phase conditions are fulfilled.

To present the problem in more detail than is possible by the use of clock diagrams, yet by following the same line of reasoning as that just given: Figures 5 and 6 are the usual curves representing three-phase and two-phase relations respectively, and it is desired to combine the curves A, B and C in such a manner that there will result two curves of equal magnitude and having 90 degrees difference in phase, this being the two-phase relation and represented in Figure 6. By taking Figure 5 and reversing curve C, the result will appear as in Figure 7, and the curves will now have a displacement of 60 degrees relative to each other. If curves B and C be laid off with their maximum ordinates proportional to 100, and if the value of A be increased to 173, the new set of curves shown at the left hand side of Figure 8 may be plotted. Combining curves B and C by adding their ordinates (see right hand side of Figure 8) produces a fourth curve marked D, which is equal to curve A' and lagging 90 degrees behind it. In other words, curves A' and D represent the two-phase relation produced by curves A', B and C; these three latter being obtained by slightly modifying the original three-phase curves.

The curves in Figure 8 may be considered as representing values of magnetic flux produced in two transformers, the flux in transformer No. 1 being represented by curve A'. Curve D represents flux in transformer No. 2, due to the resultant of fluxes B and C. The fluxes A' and D being of equal value and 90 degrees apart, the electromotive forces generated by them in the secondary coils will bear the same relation to each other, and hence produce two-phase currents.

In order to arrive at these results in practical operation, electrical connections should be made as in Figure 9, which represents

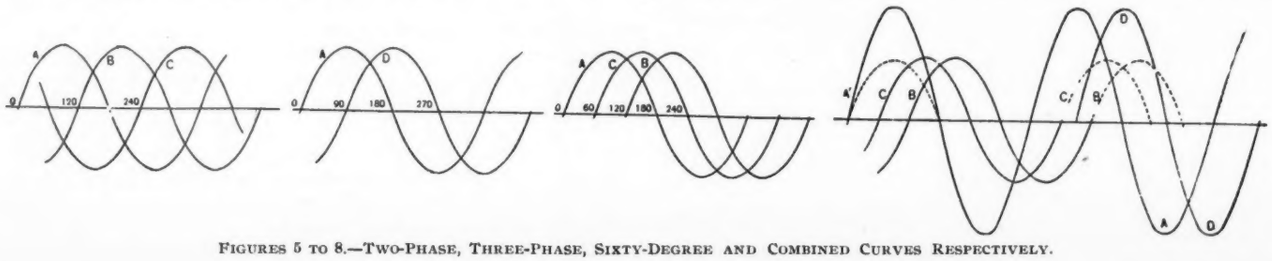


FIGURES 1 TO 4.—CLOCK DIAGRAMS ILLUSTRATING TWO-PHASE TO THREE-PHASE TRANSFORMATION.

two transformers with their primaries joined to a three-phase alternator, the secondaries being open-circuited. The figures represent the proportion in which the coils should be wound for a 1.73 to 1 ratio, and the current flowing in coil A (corresponding to curve A', Figure 8) energizes transformer No. 1, while the currents flowing in coils B and C combined (coil C being reversed) energize transformer No. 2.

It is possible to accomplish the transformation with three ordinary transformers, provided that the primaries have two coils so that connection can be made in the middle of the right hand transformer. It was shown above that for every 100 turns in each primary coil of transformer No. 2, there should be 173 turns in

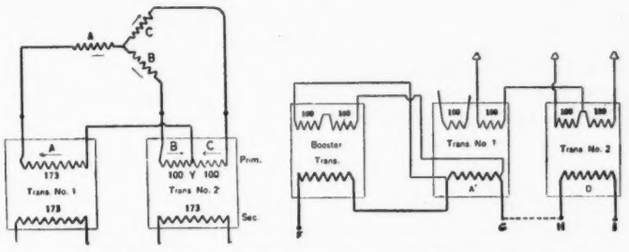
*Transactions Institution of Electrical Engineers, London, March 22, 1899.
†*Electrical World and Engineer*, Vol. XXXIV, page 120.



FIGURES 5 TO 8.—TWO-PHASE, THREE-PHASE, SIXTY-DEGREE AND COMBINED CURVES RESPECTIVELY.

transformer No. 1, in order that the magnetizing force produced by it, and represented by curve A', Figure 8, may have its proper value relative to B and C.

If in Figure 10, both primary coils of transformer No. 1 be connected as shown — for a moment not considering the effect of the boosting transformer — it would be equivalent to plotting curve A', Figure 8, to a value of 200. Hence the two-phase current obtained would be unbalanced because A' would be much higher



FIGURES 9 AND 10.—TRANSFORMER CONNECTIONS FOR TWO-PHASE TO THREE-PHASE TRANSFORMATION.

than D. On the other hand, if only one coil be used, A' would have to be drawn proportional to 100, which is obviously too low. By adding a third transformer with its secondary connected in series with coil A', Figure 10, and exciting the primary winding as shown, it is possible to obtain a boosting effect sufficient to raise A' approximately to its proper value. Very satisfactory results have been obtained in this manner from three transformers each of which had three secondary coils, by cutting out one or more of which, it was possible to obtain perfect two-phase currents.

In order to prove that two-phase current of proper form has been obtained, the middle wires of the secondary coils A', D, in Figure 10, should be temporarily joined as shown by the dotted line $G\,H$. Then, with 100 volts between F and G and between H and I, there should be 141 volts between F and I; or, in other words, these voltages should have a ratio of 1 to 1.41.

THE CALCULATION OF CONDENSER FUNCTIONS.*

THE question of the effect of condensers on alternating circuits can be treated quite simply and clearly, as far as the practical results are concerned, with only elementary mathematics in the following way. To begin with, these points can be taken as proved, as they are explained in all the text-books:

(*a*) Current flowing into a condenser = $2\pi \times$ periods per second $\times$ capacity in farads $\times$ volts at terminals. (This is correct for sine wave supply electromotive force only.)

(*b*) The condenser current is 90 degrees in phase (¼ period per second) in advance of the electromotive force; *i. e.*: the current has a positive maximum value when the electromotive force is passing through zero in a direction from negative to positive.

(*c*) If an alternating electromotive force of amount V is applied to an inductive resistance of self-inductance L henrys and R ohms, the current flowing will

$$= \frac{V}{\sqrt{R^2 + (2\pi \text{ p. p. s. } L)^2}} \text{ amperes.}$$

If the ohmic resistance is negligible this becomes $\dfrac{V}{2\pi \text{ p. p. s. } L}$ and the current is then 90 degrees (¼ p. p. s.) in phase behind the electromotive force; *i. e.*: the current has a positive maximum value when the electromotive force is passing through zero in a direction from positive to negative.

The effect of a condenser depends not only on the size of the condenser itself, but on the constitution of the circuit into which it is placed; *i. e.*: whether these are resistances either inductive or non-inductive (consisting of either lamps or motors, or even of the generating apparatus itself, such as the alternator armature or the supply transformer's coils), also connected to the circuit.

A consideration of the following five typical cases will explain how the condenser effect can be calculated under any particular circumstances. In order to make comparisons easier, a numerical example is added, using the figures:

Capacity of condenser = K = 5 microfarads (= 5×10^{-6} farad), which is about equivalent to 10 or 15 miles of ordinary concentric mains.

Non-inductive resistance, R = 100 ω.

Inductive resistance, r = 100 ω, and L = .4 henry.

Applied voltage = 1000 = V; p. p. s. = 100 per second.

Figure 1. A condenser connected in series with alternating mains, the rest of the circuit being considered non-inductive.

Current through condenser = $C = 2\pi$ p. p. s. $K\,V$,
= 3.14 amperes.

Figure 2. A condenser in series with a non-inductive resistance.

Volts across the condenser = $E = \dfrac{C}{2\pi \text{ p. p. s. } K}$

Volts across the resistance = $e = C \times R$

and these two voltages are in quadrature.

These vectorial sums must equal the whole applied electromotive force.

$$\therefore V = \sqrt{E^2 + e^2} = C\sqrt{R^2 + \left(\frac{1}{2\pi \text{ p. p. s. } K}\right)^2};$$

$$1000 = C\sqrt{10{,}000 + 101{,}000};$$

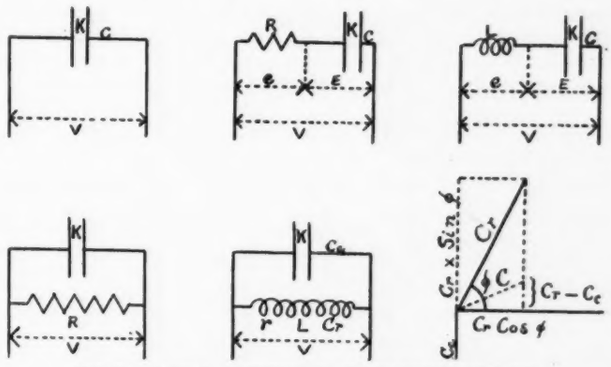
or, C = 3 amperes;

$\therefore E$ = 955 volts, and e = 300 volts.

Figure 3. A condenser in series with an inductive resistance across the mains.

The voltage across the condenser = $E = \dfrac{C}{2\pi \text{ p. p. s. } K}$, and this is 90 degrees behind the current flowing.

The voltage across the inductive resistance is the resultant of two other voltages: $C \times r$ in phase with the current, and $C \times 2\pi$



FIGURES 1 TO 6.—INDUCTANCE AND CAPACITY CIRCUITS.

p. p. s. L at 90 degrees ahead of the current — *i. e.*: 180 degrees ahead of the condenser terminal voltage — which can, therefore, be directly subtracted from it:

The resultant voltage

$$V = C\sqrt{(r)^2 + \left(2\pi \text{ p. p. s. } L - \frac{1}{2\pi \text{ p. p. s. } K}\right)^2};$$

1000 = $C \times$ 120.5; or current flowing = C = 8.3 amperes,

a larger current than either the condenser or the inductive resistance alone would have allowed to pass.

The voltage across the condenser, E, therefore

$$= \frac{8.3}{.00314} = 2640 \text{ volts;}$$

and the voltage across the resistance, e

$$= 8.3\sqrt{(r)^2 + (2\pi \text{ p. p. s. } L)^2}$$
$$= 2250 \text{ volts.}$$

This curious increase in volts above the supply voltage is due to what is known as electric resonance. Resonance occurs always to a greater or less extent when condensers and inductive resistances are connected to the same mains.

*From *The Electrical Engineer*, London, Vol. XXIV, p. 438, October 6, 1899.

Complete resonance occurs when 2π p. p. s. L is exactly equal to $\frac{1}{2\pi \text{ p. p. s. } K}$ for the whole circuit, and in that case the current flowing reaches its maximum value, *viz.*: $\frac{V}{r}$ just as if Ohm's law alone determined the current, the inductance and the capacity; having, in fact, entirely eliminated one another in such a case. The increase of voltage across the condenser is also a maximum when complete resonance is reached.

Figure 4. A condenser coupled in parallel with a non-inductive resistance across the alternating mains.

The current in the resistance $= \frac{V}{R} = 10$ amperes in phase with the applied volts.

The current in the condenser $= V \times 2\pi \times$ p. p. s. $\times K = 3.14$ amperes at 90 degrees ahead of the voltage.

The current taken from mains is the vectorial sum of these two:

$$= V\sqrt{\left(\frac{1}{R}\right)^2 + (2\pi \text{ p. p. s. } K)^2}$$
$$= 1000\sqrt{.0001 + .00001}$$
$$= 10.5 \text{ amperes (about)}$$

Figure 5. A condenser connected in parallel with an inductive resistance across the alternating mains.

The current through the resistance $= C_r$

$$= \frac{V}{\sqrt{r^2 + (2\pi \text{ p. p. s. } L)^2}} = 3.7 \text{ amperes (about)},$$

and the angle of lag of this current behind the supply volts $= \phi$ is such that $\cos\phi = \frac{\text{Current} \times r}{V} = .37$, or $\phi = 68$ degrees.

This current can be considered as made up of two parts, one being $C_r \times \sin\phi$ at 90 degrees to the supply volts, and the other being $C_r \times \cos\phi$ in phase with the supply volts. The current through the condenser $= C_c = 2\pi$ p. p. s. $K\,V$, and is at 90 degrees to the supply volts $= 3.14$ amperes.

The current taken from the supply mains is the vectorial sum of these three currents (see Figure 6), or

$$C = \sqrt{(C_r \cos\phi)^2 + (C_r \sin\phi - 2\pi \text{ p. p. s. } K\,V)^2}$$
$$= \sqrt{(3.7 \times .37)^2 + (3.7 \times .927 - 2\pi \times 100 \times 5 \times 10^{-6} \times 1000)^2}$$
$$= 1.96 \text{ amperes.}$$

For complete resonance, again, 2π p. p. s. L must be made equal to $\frac{1}{2\pi \text{ p. p. s. } K}$, and in that case no current beyond what is needed to supply the power lost in the resistance comes from the mains, though much larger currents circulate as shown between the condenser and the resistance.

MEASURING ALTERNATING-CURRENT FREQUENCY.*

BY HUBERT V. CARPENTER.

A STRETCHED wire has been shown, both theoretically and by experiment, to follow very accurately the law expressed by the formula

$$n = \frac{1}{2l}\sqrt{\frac{F}{W}}$$

Where: n = number of vibrations per second;
l = length of vibrating wire;
F = force in dynes with which the wire is stretched;
W = weight of wire in grams per centimetre length.

If we arrange the instrument so that the tension, F, is produced by a weight, the value of F is given by this weight in grams multiplied by the acceleration due to gravity which varies from 980 to 981 in this country. With F determined in this manner, there is no factor in the right-hand member of the equation which cannot be determined with the greatest accuracy in the laboratory, and with a constant source of current, results can easily be obtained within an error of one-fourth of one per cent.

In practice, with a frequency of 60, the wire to be so stretched as to have a natural frequency of 60 when the length of the vibrating segment was 60 centimetres. Then a change of one cycle per second in frequency corresponded very closely with a change of one centimetre in length of the wire. This is based upon the condition that when the wire is 60 centimetres long its frequency is also 60.

As an example of the calculations, take the case of a steel piano wire which weighs .00785 grams per centimetre of length. What weight will need to be used to stretch it so that a segment of it 60 centimetres long will vibrate with a natural frequency of 60? From the above formula if $n = 60$, $l = 60$, $W = .00785$ and $F = w \times g$, where w is the stretching weight in grams and g is the acceleration due to gravity, g is equal to about 980.6 in central Illinois, so if we substitute these values we have,

$$60 = \frac{1}{2 \times 60}\sqrt{\frac{w \times 980.6}{.00785}}$$

$w = 414.99$, or practically 415.0 grams.

Assuming lengths of 60, 62.5 and 66.5 centimetres for the wire, the accompanying table gives the weights necessary to stretch various kinds and sizes of wires to the proper tension to make their natural frequency of 60, 125 and 133.

For 125 and 133 cycles the weights are given which make $l = 62.5$ and 66.5 centimetres respectively, so that a change of 0.5 centimetres indicates a change of one cycle very closely.

If English units of length and weight are preferable, the formula becomes

$$n = \frac{9.824}{l\,(\text{inches})}\sqrt{\frac{\text{oz. (tension)}}{\text{oz. per in. length}}}$$

30 inches, 31¼ inches and 33¼ inches are good lengths to use for the three frequencies mentioned because a change of one-half inch in the first and of one-quarter inch in the last two corresponds closely to a change of one cycle per second in frequency.

As an example, let us take the same wire as used in the first problem: diameter = .0141 inches, weight per inch = .0007034 oz. Find the stretching weight for a length of 30 inches and a frequency of 60 cycles per second.

$$n = \frac{9.824}{l}\sqrt{\frac{w}{W}}$$

$$n = 60 \quad l = 30 \quad W = .0007034$$

$$w = \frac{n^2\,l^2\,w}{9.824^2} = \frac{\overline{60.}^2 \times \overline{30.}^2 \times .0007034}{\overline{9.824}^2} = 23.671 \text{ oz.}$$

It will be noticed that the weight varies directly as the weight of the wire per unit length, and also directly as the square of the frequency and as the square of the length of the vibrating segment. This reduces the work necessary to get the result under different conditions to a very simple calculation.

WEIGHT AND TENSION OF WIRES.

Wire			Stretching Weights in Grams and Ounces					
			$n = 60$ $l = 60$ Cm		$n = 125$ $l = 62.5$ Cm		$n = 133$ $l = 66.5$	
Diam. in Cm.	Material	Grams per Cm. Length.	Grams.	Ounces.	Grams.	Ounces	Grams.	Ounces
.150	Steel piano wire.	0.138	7705.3	257.34	34335	1211.9	44090	1555.1
.098	" "	0.00785	414.905	14.638	1924.3	68.040	2404.8	84.870
.046	Phosphor bronze.	0.0143	756.0	26.668	3506.3	123.69	4383.4	154.67
.0819	Copper	.0460	2432.8	85.860	11282	403.98	14077	519.70

Stoeckhardt's method* for measuring frequencies exactly, if their values are known approximately, possesses the advantage of marked simplicity. The instrument used consists of a wrought iron tuning fork and a coil with a soft iron core between the prongs, which are provided with adjustable weights, so that the period of the oscillations can be altered. When adjusted so that the note of the fork becomes a maximum, the periodicity of the current in the coil is a multiple of that of the oscillations of the note. In the Stoeckhardt instrument the adjustable weights on the fork are moved along a scale determined empirically and giving the value of periods between 90 and 120. The results of a test show that the instrument enables very sharp readings to be taken, the errors being below one-quarter per cent.

*Abstract from the *Electrical World and Engineer*, Vol. XXXIV, No. 6, page 198, August 5, 1899.

*Described in *Elek. Zeit.*, December 14, 1899.

Obituary

SAMUEL DANA GREENE. The whole electrical world laments the distressing accident which resulted in the drowning of Lieutenant S. Dana Green and wife, on January 8th, while skating on the Mohawk River near Schenectady N.Y., an accident which shocked countless legions of friends and admirers into heartfelt grief. To the General Electric Company, of which he was manager of the supply department, his loss will be most keen, for of all its very popular officials, Dana Greene was truly the most lovable and loved.

Lieutenant Greene was thirty-five years old and the son of the late Commander S. Dana Greene, who succeeded to the command of the "Monitor" after Admiral Worden was disabled in the famous fight with the "Merrimac," and was a nephew of Major-General Francis Vinton Greene. He is survived by his mother, one brother, Lieutenant George D. B. Greene, formerly adjutant of the Second Regiment New York Volunteers during the Spanish-American war, and a sister, Mrs. J. S. Conover, all of Schenectady.

Lieutenant Greene entered the Naval Academy in 1879, graduating at the head of his class in 1883. During the entire four years at the academy Lieutenant Greene stood at the head of the class, which originally contained more than one hundred members and which graduated fifty-four. His academic career in fact was one of the most notably brilliant in the history of the Naval Academy. After a short term of service at sea he became actively connected with the old Sprague motor interests, followed them into the Edison General Electric Company, and then on the consolidation of that with the Thomson-Houston Company, became prominently identified with their successor, the General Electric Company. In this corporation he again came to the front, rising rapidly until at his death he was in full charge of all the sales as general sales manager. His great acquaintance with the technique of the art was reinforced by considerable executive ability, and by a gracious *savoir faire* and gentleness that made him deservedly a universal favorite.

During the Spanish-American war Lieutenant Greene, who had taken great interest in the formation of the Naval Reserve, went to the front and was under fire as the executive officer of the auxiliary cruiser "Yankee." Since the peace he had been serving on the staff of Governor Roosevelt, of New York State, as naval attaché, with the rank of lieutenant-commander. He took a deep interest in naval affairs and presented papers on electrical-naval topics before various bodies connected with the navy. He was also a valuable contributor to the proceedings of the American Institute of Electrical Engineers and to those of the New York Electrical Society. Our own columns have from time to time been graced by communications from his pen. An important work to which he had of late devoted attention and energy is the standardization of electrical apparatus and its testing, etc.

Mrs. Greene was the daughter of the late Rear-Admiral Ralph Chandler, on officer of brilliant attainments and high professional standing, who died February 11, 1889, at Hong Kong while flag officer of the Asiatic station. The marriage took place a few years ago after a courtship of more than ordinary ramance, and it would have been hard to find a more attached and loving pair. Their home life at Schenectady was simply delightful, and one of the sad features of the terrible affair is that Lieutenant Green had just bought a site for a country home in Saratoga county, near Schenectady. The funeral took place at Schenectady on January 11th, the interment being at Bristol, Rhode Island.

Arenzano, Italy, possesses a direct-current, three-wire system for incandescent lighting service, with 500 volts between the outside wires and 250 volts between the neutral and either outside wire, 250-volt incandescent lamps being used. The installation is briefly described in *L'Electricien* for May 13, 1899.

Electro-Economics

EFFICIENCY OF THE NIAGARA GENERATORS.

IN determining the efficiency of the new 5000-horsepower generators for the Niagara plant, the iron losses were estimated by driving the dynamos under test by motors and noting the increase in the power absorbed when the fields were excited. The copper loss was, of course, readily calculated, and the iron loss under load was estimated from that obtained by the test described by assuming an increased maximum induction due to load distortion and correcting the hysteresis loss in proportion to the 1.6-power thereof. The iron loss at full load was thus determined to be only 32.1 kilowatts, the armature copper loss being 28.7 kilowatts, and the field copper loss 7.4 kilowatts, giving an electrical efficiency at full load, 3750-kilowatt output, of over 98 per cent.

The machines, on continuous run, at full open gate reach a limiting temperature only 47 degress C., above that of the atmosphere. This is about a ten per cent. overload, the rated load of the machine being attained at about nine-tenths gate. Temperature measurements are obtained by so-called exploring coils, consisting of No. 36 copper wire wound on a card in such a way that it can be slipped into narrow passages such as the ventilating ducts. The machine takes about five hours to come to a fixed temperature.

Literature.

"American Telephone Practice," by Kempster B. Miller, M. E. 458 pages, 8-vo., cloth, 6x9 inches, 359 figures, circuit diagrams, etc., first edition; published by the American Electrician Company, 120 Liberty street, New York. Price $2.00.

The literature of American electro-techinques is pretty scant in some directions, but there is no line in which there has been such woeful meagerness as in telephone engineering. England has its telephone status well presented in Preece and Stubbs' "Manual of Telephony," the continent too has books which present the state of the science very satisfactorily, but until the present time American engineers could point to no work on American telephone practice which was much more than mere babble.

To understand why this has been so necessitates a review of the telephone situation in America, to grasp which no one can do better than to refer to a recent contribution to *The Engineering Magazine** by the author of the present work, wherein it is shown that a more complete monopoly than that enjoyed by the American Bell Telephone Company throughout its existence, until the early part of 1893, probably never existed. This monopoly was based primarily on the fundamental patent of Alexander Graham Bell, covering broadly the art of transmitting speech by electricity, and, secondarily, on many hundreds of patents of greater or less importance covering methods and apparatus used in practical telephony. These later patents were the result of a wise, far-seeing and persistent policy on the part of the Bell company and its manufacturing company, the Western Electric Company of Chicago, to secure to themselves the right to manufacture and use all the inventions made by the engineers in their employ, and also to buy up all inventions of merit made by outsiders. So close-meshed was the web thus woven that it was thought that, even after the expiration of Bell's fundamental patent, the monopoly would still be maintained; for of what use would the broad art of telephony be to the general public if *all* of the apparatus and means for putting it into effect were still under the control of a single company? Thus it was that the Bell company controlled not only all the patents that were worth controlling, but practically all the men and consequently all the knowledge that was worth having. Telephone engineering, unlike all other branches of electrical engineering, was not taught in the colleges, and all these circumstances conspired to prevent the publication of any work that should be at once practical, comprehensive and of real value to the engineer as reliably portraying the almost infinite de-

*Volume XVIII, No. 4, page 550, January 1900.

tails attending the operation of American telephone systems and practices.

Mr. Miller's most excellent book has changed this situation at a single stroke. But, after all, its appearance is only in keeping with the general telephone situation, which is to-day entirely changed from that above depicted. Many strong patents have expired; weaker ones have been declared invalid by the courts; while others are, in the estimation of the public, so palpably weak that they are quietly ignored. The knowledge of telephone matters has grown with the demand for cheaper and better service. Good telephone men have been created from available raw material, and many old ones have abandoned their primary training with the Bell company for the apparently brighter prospects of the independent telephone field. The new situation, then, has made it possible for such a book as "American Telephone Practice" to appear.

Though a young man, Mr. Miller's name is well known in ths engineering world through his many contributions to the electrical press. When fresh from Cornell University he began his technical work at the factory of the Thomson-Houston Electric Company at Lynn, Mass., going thence to the shops of the Westinghouse Electric and Manufacturing Company at Pittsburg; next he entered the United States Patent Office, and after a successful period of service there he entered the independent telephone field, in which he is now recognized as one of its leading engineers. Had there have been a doubt in any mind concerning his ability as a telephone engineer that doubt would be quickly dispelled by any one who would even scan the truly invaluable work he has now brought out.

As to the book itself, it, perhaps for the first time, commands into activity the latent admiration which the engineer in other lines of electrical work has always had for the marvels that have been accomplished by the telephone engineer—the engineer, who, above all others, has ever been the foremost to hide his light under the proverbial bushel. The problems of telephony are no less intricate than are those attending alternate current work—indeed, the problems of telephony really are those of alternate current work, compounded with unparalleled complexities peculiar to themselves. No attempt whatever has been made in the present book to handle these problems from their mathematical standpoints, that being beyond the scope of the work, but instead both the theory, and particularly the practical applications, apparatus and methods in use in this country are exhaustively described in a manner that is equally impartial to the Bell and independent companies. Thirty-three different subjects are discussed under as many different chapter headings, and one notes with interest that the latest types of apparatus, including even the Bell common battery visual signal boards, are not only described in detail, but are explained thoroughly by means of circuit diagrams.

"CALIFORNIA MINES AND MINERALS." A souvenir volume presented to the members of the American Institute of Mining Engineers by the California Miners' Association.

One of the many pleasing features of the Thirtieth Annual Convention of the American Institute of Mining Engineers, recently held in San Francisco, was the presentation to each of its members with the copy of a beautiful and exceedingly valuable book, entitled "California Mines and Minerals," by the California Miners' Association, as a souvenir of the meeting. This is a work of 450 pages, compiled under the direction of Edwaid H. Benjamin, Secretary of the California Miners' Association, and a review of its contents speaks eloquently the fact that the compilation was a matter of love, for very rarely, if ever, will one find such evidences of painstaking care and devotion bestowed upon the preparation of a volume whose aim is monetary gain, as Mr. Benjamin has given to this work, which is not for sale and which represents the fruit of a labor of love, as stated.

Its limited though very select circulation (it was presented only to members of the Mining Institute and is not to be obtained by the general public) precludes the necessity for its formal review.

Industrial

In responding to advertisements in this publication kindly mention "The Journal of Electricity, Power and Gas."

ANNUAL MEETING OF THE WAGNER COMPANY.

The annual meeting of the Wagner Electric Manufacturing Company was held in St. Louis, Mo., on January 8th, during which the old board of directors, as well as officers, were re-elected as follows: S. M. Dodd, president; James Campbell, vice-president; S. B. Pike, secretary and general manager; W. A. Layman, treasurer and assistant general manager; Ferd Schwedtmann, general superintendent; E. H. Abadie, manager sales department. Directors—S. M. Dodd, James Campbell, James W. Bell, J. C. Van Blarcom, S. B. Pike, Ferd Schwedtmann, H. A. Wagner.

The reports of the officers there represented showed an increase in the company's business during 1899 as compared with 1898 of 68.5 per cent. By vote of the board a dividend of 8 per cent. was declared, payable March 10th.

During the year there have been many rumors current to the effect that the majority of the stock holdings of the Wagner company had been disposed of to some of its Eastern competitors and that the business was now fully under the control of these competitors. All these rumors have been absolutely without foundation. The stock is held entirely by St. Louis parties, and the officers and directors of the company are all representative St. Louis business men. The year just closed has been one of the most successful in the history of the company, being especially marked by a large number of important contracts calling for a high grade of engineering work.

NEW ELECTRICAL CORPORATIONS.

The Peninsula Electric Lighting Company of Redwood City and Palo Alto, the San Mateo Gas Company and the San Mateo Electric Lighting Company have been absorbed by a number of San Francisco capitalists, and are to be operated as the Consolidated Light and Power Company of San Mateo and Santa Clara counties. The authorized capital of the new concern is 50,000 shares at $10 a share. Of this amount, 25,000 shares have been subscribed. Among those in the deal are Pce. Poniatowski, William H. Crocker, C. E. Green, Henry T. Scott, W. Frank Pierce, T. S. Bullock, R. J. Davis, George W. Kline, J. M. O'Brien, Saura B. Roe, J. E. Green, Hugh Keenan, Edward Pollitz & Co., A. F. Morrison, W. B. Cope and John J. Maloney.

The San Francisco Light and Power Company was incorporated on December 16th, with a capital stock of $1,000,000, the incorporators being Pce. A. Poniatowski, William H. Crocker, Henry T. Scott, Frank W. Pierce, Charles E. Green, Joseph E. Green and William Angus, of San Francisco, and Ernest Thalmann, of Ladenburg & Thalmann, of New York, and William J. Latta, president of the recently organized Telegraph and Telephone Company of America, the capital stock of which is $30,000,000.

A NEW ELECTRICAL SUPPLY COMPANY.

Announcement is made of the incorporation on December 26, 1899, of the General Supply Company, San Francisco, by the following parties: M. F. Pixley, president; A. W. Sissons, vice-president; Geo. E. Whitaker, secretary; P. A. Reger, manager, and E. Hessler, director. The capital stock is $25,000, and the company's place of business is located at 537 Mission street, San Francisco.

"Guide to the Selection and Testing of Incandescent Lamps." A 34-page illustrated book of instructions dealing with the subject named. It discusses physical defects, ratings, diagrams, candle power, efficiency, deterioration, renewal of dim lamps, the photometer and photometric measurements with diagram of connections therefor, and the relative values and limits of useful lives of lamps. Instruction book No. 8084. *General Electric Company.*